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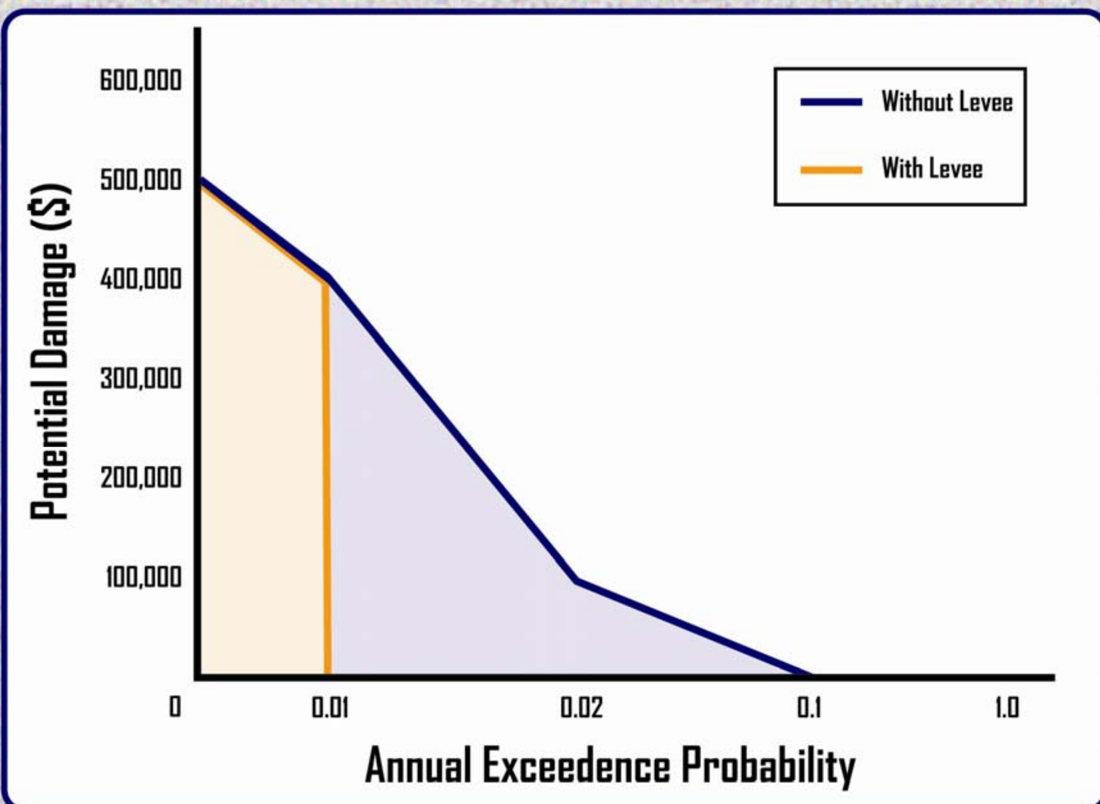
Economic Analysis Guidelines Flood Risk Management



May 2010

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Flood Risk Management
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Chapter 1: Introduction

Purpose of Guidelines

The purpose of these guidelines is to provide consistent economic analysis guidance for the increasing number of DWR programs that include flood management objectives, such as the:

- California Water Plan,
- Central Valley Flood Protection Plan,
- State Plan of Flood Control,
- Regional flood management planning,
- Delta Risk Management Strategy, and
- Various bond grant programs, including (but not limited to):
    - Early Implementation Program,
    - Local Levee Urgent Repairs,
    - Delta Levees System Integrity,
    - Floodway Corridor, and
    - Stormwater Flood Management

Although many of these programs are concerned with riverine flooding, these guidelines should be applicable for other types of flooding as well, such as coastal and alluvial fans.

These DWR guidelines are being developed at a time when the science of evaluating the economic effects of flood management programs is rapidly changing. Previously known as flood control and flood damage reduction, these programs were often single-purpose (or multi-purpose with one purpose being predominant) for which the economic analysis focused only upon net benefits and benefit/cost ratios, which primarily included avoided damage to structures and other physical assets. However, for the past several years, it has been increasingly recognized that these programs must focus upon all aspects of *flood risk management*, i.e., they must evaluate, communicate, and mitigate all risks society faces from flooding. Thus, the focus of the economic analysis must be broadened to not only develop net benefit analyses based primarily upon the loss of structures and other physical assets, but also upon regional and social effects. This was further reinforced following the devastating effects of Hurricane Katrina, after which it became apparent that neighborhoods and even entire communities may not recover following that catastrophic event. Currently, intensive research is underway by the USACE, FEMA, and other organizations on how to incorporate regional and social considerations into the economic (or, more appropriately, socioeconomic) analysis. As this information is developed, it will be incorporated into these DWR guidelines. Thus, these guidelines are very much a "work in progress".

The Role of Economic Analysis in Flood Risk Management

Economics is the study of how and why people make decisions about the use of valuable resources to obtain maximum net benefits, or economic efficiency. Although efficiency is not the only goal of society, the measurement of changes in efficiency through economic analysis provides a key framework to compare alternative courses of action:

> An integrated approach to flood management requires land and water in a river basin to be considered as a single unit and aims at minimizing the losses of life from flooding while maximizing the net benefits derived from flood plains. The net benefits are the overall benefit a society derives from using flood plains (such as agricultural output and other economic activities) minus the overall cost of using the floodplains (flood damages, cost of flood protection, habitat loss, etc.) Assessing the net benefits from flood plains involves understanding the social, economic and environmental dimensions of flood risks. It requires a trade-off between development potential and the risks society has to take in occupying flood plains.[1]

Thus, conceptually, economics examines the efficiency (net benefits) of floodplain use which can be used to compare alternative plans:

[1] Associated Programme on Flood Management, *Economic Aspects of Integrated Flood Management*, June 2007.

Net benefits of floodplain use =

Benefits of using floodplains (increased economic activity, etc.)

Minus

Costs of using floodplains (flood losses, flood mitigation costs, loss of habitat, etc.)

Unfortunately, the practical application of economic analysis to identify net benefits of floodplain use becomes very complex because of the numerous direct/indirect, tangible/intangible, benefits and costs. Thus, a net benefit analysis will take into account a wide variety of quantitative and qualitative information and not rely just on the ranking of plans based upon monetized net benefits or benefit/cost ratios which often focus upon a narrower set of benefits and costs. This type of a net benefit analysis more closely resembles a socioeconomic "impact analysis" requiring the input of not only economics, but also demographics and sociology.

Invariably within most plans there will be tradeoffs that must be identified, quantified, monetized (if possible), and finally, evaluated as to not only how well the alternative plans achieve their specific program objectives, but also how well they achieve regional as well as the State's goals. For example, an agricultural or rural area that benefits from a flood risk management project may be opened to urban development, thereby meeting local and regional economic growth goals. But, such development may also come at the expense of increased residual risk for the larger population expected to occupy the floodplain and the loss of natural floodplain beneficial functions and associated societal benefits.

This "net beneficial effects" analysis is further complicated because of the potentially large geographic scope of flood risk management projects and programs. Floods do not respect political boundaries, so any evaluation of flood-related problems and proposed solutions should be conducted form a watershed perspective. USACE guidance succinctly describes this watershed perspective:[2]

[2] USACE, ER 1105-2-100, Planning Guidance Notebook, April 22, 2000, pg. 2-16.

> Civil works planning should incorporate a watershed perspective, whether that planning involves a project feasibility study or a more comprehensive watershed study. Such planning should be accomplished within the context of an understanding and appreciation of the impacts of considered actions on other natural and human resources in the watershed. In carrying out planning activities, we should encourage the active participation of all interested groups and use the full spectrum of technical disciplines in activities and decision-making. We also should take into account: the interconnectedness of water and land resources (a systems approach); the dynamic nature of the economy and the environment, and the variability of social interests over time. Specifically, civil works planning should consider the sustainability of future watershed resources, specifically taking into account environmental quality, economic development, and social well-being.

USACE and DWR Flood Risk Management Guidance

Because of its considerable water management partnerships with the federal government, the Department of Water Resources (DWR) has a policy that all economic analyses conducted for its internal use on programs and projects be fundamentally consistent with the federal *Economics and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (*P&G*), which was adopted by the US Water Resources Council on March 10, 1983. The *P&G* set forth *principles* "…intended to ensure proper and consistent planning by federal agencies in the formulation and evaluation of water and related land resources implementation studies…" and *guidelines* that "…establish standards and procedures for use by federal agencies in formulating and evaluating alternative plans for water and related land resources implementation studies."

It is also DWR policy to adopt, maintain, and periodically update its own *Economics Analysis Guidebook*, which is consistent with the *P&G* but can also incorporate innovative methods and tools when appropriate. This policy is necessary because (a) the *P&G* has not been updated for almost 25 years, (b) federal and State economic analyses sometimes have different regional analysis perspectives, and (c) water management projects and programs have become more complex. For flood risk management projects, DWR will strive to meet USACE plan formulation requirements when partnering with the USACE and/or requesting federal funding. However, if after meeting these requirements, DWR believes that the use of innovative methods which may deviate from current USACE practices but which may also help identify a "locally preferred plan", then these methods will be utilized.[3] When this occurs, collaboration will be required between the USACE, DWR and potential local sponsors as to the implications of using these methods upon federal cost-sharing requirements.

Risk

A primary objective of flood risk flood management projects is the reduction of risk resulting from the exposure of human and natural resources to flood waters. In its broadest sense, flood risk is a function of the frequency of flood events over time and their corresponding damage and other consequences. Smaller, frequent events that cause less damage may – over time – contribute to just as much (if not more) of a flood risk than extreme, but very infrequent, flood events that cause great damage. If levees or other structural flood protection facilities are present, the frequency of flooding may be reduced, but if the facility fails or is overtopped, the consequences can be devastating.

It is impossible to forecast the exact value of flood damage that would be incurred in any given year. Therefore, flood evaluations are based upon long-term statistical averages which account for frequencies of various flood events and their consequences which are combined into a single number by summing the products of all possible damage values and the likelihood of their occurrence, otherwise known as *expected annual damage*:

$$\text{EAD} = \sum_{i=1}^{n} P(x) * C(x)$$

where:

- P(x) = the probability of flood event x, and
- C(x) = the consequences of flood event x.

EAD is discussed further in Chapter 2 Benefit-Cost Analysis.

[3] DWR *Economic Analysis Guidebook*; January 2008.

Economic Analysis vs. Financial Analysis

A common misconception is that economic and financial analyses are the same. Although both are required to determine overall project feasibility and sometimes use the same data, they are conceptually different types of analyses.

The objective of economic analysis is to determine if a project represents the best use of resources over an analysis period (that is, the project is economically justified). The test of economic feasibility is passed if the total benefits that result from the project exceed those which would accrue without the project by an amount in excess of the project costs. This can be mathematically expressed as either net benefits or the benefit/cost ratio. The objective of financial analysis is to determine financial feasibility; that is, whether someone is willing to pay for a project and has the capability to raise the necessary funds. The test of financial feasibility is passed if (a) beneficiaries are able to pay reimbursable costs for project outputs over the project's repayment period, (b) sufficient capital is authorized and available to finance construction to completion, and (c) estimated revenues are sufficient to cover allocated capital and operations, maintenance and replacement costs over the repayment period.

The distinction between these two types of analyses is especially important for flood risk management programs which focus upon economic losses:

> "The intention of economic analysis as part of a flood loss assessment is to assess the deviation from likely economic activity as a result of the flood, not to take into account the financial losses to individual enterprises." [4]

Two examples:

- An owner of a firm is inundated from a flood event may suffer losses in net income. However, another competitor outside of the flooded area may be able to substitute goods from its own stock and therefore benefit from increased income. Thus, the economic

[4] APFM, *Conducting Flood Loss Assessments: A Tool for Integrated Flood Management*, March 2007.

effect resulting from the flood event is the net difference among the firms and not the loss to the flooded business owner.[5]

- Property owners in a flooded area will suffer damage to structures and their contents as well as other physical assets. From a financial point of view to the individual, these losses would be valued based upon full replacement costs. However, from an economic point of view, the valuation is based upon depreciated replacement value which takes into account the remaining economic life of the assets before they were damaged.

Table 1 summarizes the differences between economic and financial analyses.

[5] The loss to the flooded business owner is still important, however, and can be included elsewhere in the analysis as discussed below.

Table 1: Comparison of Economic and Financial Analyses

	Economic analysis	Financial analysis
Analysis perspective	Can vary from individuals, communities, state, and/or national; DWR uses statewide perspective	Project beneficiaries
Evaluation period	Economic life of project (usually 50 to 100 years)	Bond repayment period (usually 20 years)
Adjustment for inflation	Exclude inflationary effects; price changes different from inflation can be included (escalation)	Include inflationary effects
Project input valuation	Project inputs valued using their economic opportunity costs.	Project inputs valued using their purchase costs
Adjustment for benefits and costs over time	Determine present values using economic discount rate	Determine present values using financial discount rate
Discount rate	Economic discount rate; real rate of return (excluding inflation) that could be expected if money were invested in another project; DWR currently uses 6%	Financial discount rate; financial rate of return (including inflation) that could be expected if money were invested in another project; DWR uses expected interest rate of bonds sold to finance project
Interest paid on borrowed funds during construction	Not included (financial cost)	Included; DWR uses State revolving fund cost
Forgone investment value during construction	Included; real rate of return that could be expected if construction funds were invested in another project (opportunity cost)	Not included
Financial costs	Not included	Included

Chapter 2: Benefit-Cost Analysis

Perspectives

Economic analysis greatly depends upon whose perspective is being considered in the evaluation. For flood risk management projects that could potentially involve State and federal participation, the following perspectives are relevant:

- Individuals: flood risk management projects provide direct outputs to individuals and firms located within floodplains. The value of these outputs, or benefits, is measured by the willingness of individuals and firms to pay for additional flood protection.

- Communities: the provision of additional flood protection may also provide indirect economic benefits to communities as existing economic activity (regional income, employment, etc.) may be stimulated within the flood protected area. This increased economic activity is vey important to the community, but not necessarily to the State or nation.

- State: the State perspective in funding flood risk management programs is to provide benefits for all state taxpayers. If a flood risk management program stimulates economic activity in one community, it may be at the expense of another community within the State which looses economic activity. This basically represents a "transfer" of economic activity within the State, with one community the "winner" and another the "loser", therefore not a benefit to the State.

- Federal: the federal perspective is similar to the State's, except that it is for the entire nation. The federal objective is to provide benefits for all the nation's taxpayers. Improved flood protection that stimulates economic activity in one state may do so at the expense of economic activity foregone in another state, thus this is basically a "transfer" of economic activity and not a benefit to the nation.

These perspectives are critical to understanding the federal planning accounts discussed in Chapter 3.

Planning Time Horizon

The planning time horizon extends from the beginning of the study to the end of the project life, as shown in Figure 1.[6] The planning horizon includes planning and design, construction and project life after construction. A subset of project life is the period of analysis over which any alternative plans considered would likely to have significant beneficial or adverse effects. Typical analysis periods for structural water resource projects are 50 to 100 years; for projects considered under the FloodSAFE program, the economic analysis will be based on a analysis period of 50 years unless other information is available that would show that a different period of analysis should be used. If the period of analysis is shorter than the project's life, then it may be possible to deduct a salvage value, but often such a detailed analysis is not warranted because of discounting since this adjustment occurs at the end of the analysis period.

Other critical concepts within the planning horizon include:

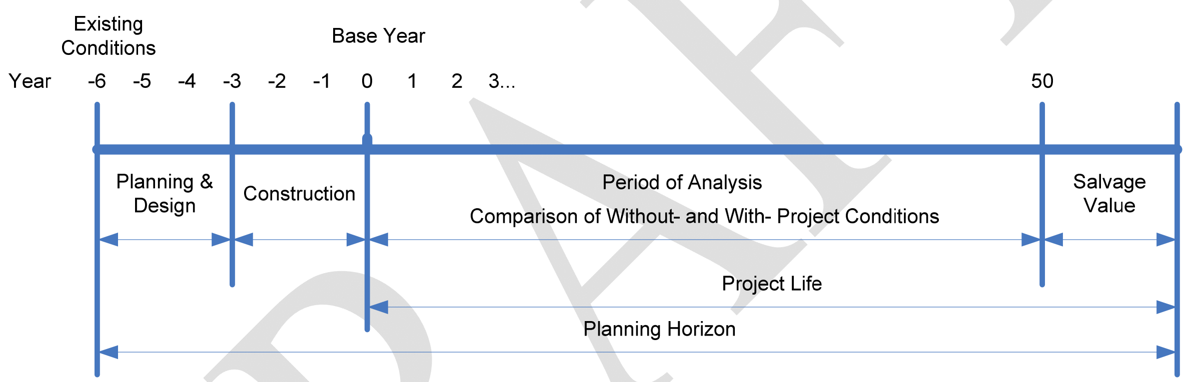
- Existing conditions: conditions at the time the study commences.
- Base year conditions: a forecast of conditions that describes the study area at the time when the project begins operation; this may be several years from existing conditions and in rapidly urbanizing areas, significant growth could occur between existing and base year conditions; other flood risk management projects expected to come on line (or are approved and funded) by the "base year" should be included.
- Without-project condition: a forecast of conditions over the period of analysis which describes what the study area would be like if no project is implemented as a result of the study; without-project conditions remain the same regardless of the number of alternatives under study. The development of the without-project condition is one of the most important tasks of a flood risk management study; this task is described further in the USACE's new National Economic Development Manual for Flood Damage Reduction Studies.[7]

[6] Project life can be further distinguished between economic life and physical life: the economic life is the period in which the project is economically viable, which means that the incremental benefits of continued use exceed the incremental costs of that use. Physical life is the period in which the project can physically perform its intended function. Economic life may be shorter than physical life but not vice versa.

[7] http://www.pmcl.com/nedprototype/index.asp

- With-project condition: a forecast of conditions over the analysis period which describes what the study area would be like if a project is implemented as a result of the study; if there are several alternatives which may significantly affect with-project conditions, then several with-project conditions may need to be defined. If population growth is included in the with-project condition, then the economic analysis should be conducted based upon both the existing year and projected conditions over the analysis period.

Figure 1: Planning Time Horizon



Assumptions

Economic analysis conducted for DWR flood risk management programs should utilize these fundamental assumptions:

Inflation and escalation

To simplify the economic analysis, applicants will generally assume zero future construction cost inflation and escalation (i.e., cost increases exceeding the general level of price inflation). However, if future escalation can be identified, it can be included in the economic analysis if assumptions are documented. In contrast, financial analyses account for inflationary effects.

Discount rate

The discount rate is used to adjust dollars received or spent at different times to dollars of a common value, usually present day dollars ("present worth" or "present value"). Although there are different methods for determining discount rates, generally the value to use for this rate is the real (that is, excluding inflation) rate of return that could be expected if the money were instead invested in another project. In other words, the discount rate is a measure of forgone investment opportunity (that is, "opportunity cost") if the money allocated to the project were invested elsewhere.

The selection of a discount rate is critical for the analysis because the larger the discount rate, the greater the reduction in future monetary values. This tends to affect benefits more than costs because the majority of costs are incurred early in the analysis period (for example, construction costs); whereas, benefits typically occur later in the analysis period. DWR is currently using a 6% discount rate, which approximates the marginal pretax rate-of-return on an average investment in the private sector in recent years. This rate will be periodically reviewed and revised as necessary. The US Treasury Department annually sets the discount rate used by the USACE.[8] The discount rate is very much different from the bond repayment interest rate that is used in a financial analysis.

Dollar base year

All benefits and costs will be expressed in current year dollars. If dollar estimates are only available for prior years, these can be updated using a variety of cost indices. To update project construction costs, appropriate indices include the US Bureau of Reclamation Construction Cost Indices (www.usbr.gov/pmts/estimate/cost_trend.html), the Engineering News-Record Construction Cost Index (enr.construction.com), or the US Army Corps of Engineers' (USACE) Civil Works Construction Cost Index System (www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-1304/entire.pdf). To update building stock construction costs, Marshall & Swift (or a similar appraisal services company) comparative cost multipliers can be used (http://www.marshallswift.com). Finally, a useful "all purpose" index is the Gross Domestic Product Implicit Price Deflator (www.research.stlouisfed.org/fred2/series/GDPDEF/21). The analysis should identify which cost index is used.

[8] The USACE discount rates are included in their Economic Guidance Memorandum found on their General Planning Guidelines website: http://www.usace.army.mil/cw/cecw-cp/library/planlib.html

Depreciated vs. full replacement structural values

For flood risk management analyses, structures that are potentially inundated with flood water must be valued using depreciated replacement cost and not full replacement costs. The use of depreciated replacement costs takes into account that structures may have a portion of their economic lives "used up." Typically depreciated replacement values are calculated as:

Depreciated replacement value = structure square footage X
current replacement costs ($/square foot) X
depreciation factor (% remaining life)

As discussed above, depreciated replacement costs are a more appropriate measure of economic costs because they take into account the remaining economic life of the assets.[9]

Benefit-Cost Analysis Overview

Economic analyses performed for proposed flood risk flood management projects estimate potential flood losses expected to occur over an analysis period for without project conditions and then compare these to consequences expected to occur with a proposed project. The reduction in flood losses attributable to a project are its benefits which can then be compared to project costs to determine if the project is economically justified. Flood damage and other flood-related costs can be expressed as either *event* or *expected annual damage*. Event damage results from specific flood events (e.g., 50-, 100-, 200-, and 500-year); event damage estimates are useful for characterizing damage potential from specific magnitude storm and associated emergency planning purposes and are input into expected annual damage calculations. Expected annual damage (EAD) is the damage that could be expected to occur in any given year taking into account all different types of flood events. Differences in the total present value of EAD between without- and with-project conditions over the analysis period provide an estimate of the benefits which are then compared to the total present value of costs of the proposed project to determine net benefits or a benefit/cost ratio.[10]

[9] The USACE uses depreciated replacement values but the Federal Emergency Management Agency typically uses full replacement values. One reason for this difference in approaches may be that FEMA focuses upon disaster mitigation and must often pay the financial costs for repairing or replacing damaged structures and other assets regardless of the asset's prior economic condition.

[10] Benefits and costs may also be analyzed on an annual basis. Annualized EAD values over the analysis period are sometimes called equivalent annual damage.

The general steps for determining flood damage reduction benefits are:

- Identify at least three flood events for which flood conditions and associated flood damage will be different for without- and with-project conditions;
- Identify existing *without-project* conditions:[11]
    - Determine area affected by flooding for the identified flood events;
    - Estimate number and values of structures affected by flooding by each event;
    - If flood management structures are present (such as levees, culverts, etc.), determine probability of failure by event; and
    - Estimate flood damage for *without-project* conditions for each event.
- Identify existing and future *with-project* conditions:
    - Determine area affected by flooding for the identified flood events;
    - Estimate number of and values structures affected by flooding by each event;
    - If flood management structures are present (such as levees, culverts, etc.), determine probability of failure by event; and
    - Estimate flood damage for *with-project* conditions for each event.
- Calculate expected annual flood damage as described below for *without*- and *with-project* conditions; and
- Calculate the expected annual flood damage reduction benefit as described below.

[11] A critical question in determining without- and with- project conditions is whether to include future population growth, which raises issues whether that growth meets FEMA National Flood Insurance Program building elevation/floodproofing requirements within the regulatory "100-year" floodplain. To avoid these issues, DWR generally requires that flood damage reduction analyses should, at a minimum, be conducted based upon existing conditions. Chapter 4 further discusses the issue of including future population growth.

Expected annual damage (EAD) is the amount of annual flood damage estimated to occur *on average*, taking into account all different types of flood events that might occur. EAD must be calculated for the without-project and the with-project conditions. EAD is a function of three variables:

- The probability of an event occurring that could result in flooding;
- The probability that, if present, any flood management structures (such as a levee or culvert) fail given the event's occurrence; and
- The resulting damage if the structural protection fails.

Example analysis

Table 2 and Figure 2 illustrate how to estimate EAD for the without-project and with-project conditions. Table 2 identifies five hydrologic events that could result in flooding for an area with some form of structural flood protection (levee, culvert, etc.). The probability of an event resulting in flooding depends on the without- and with-project level of protection provided by flood protection structures (if present). As shown in Table 2, there is a 50 percent chance a 10-year event will result in flooding without the project because of structural failure. With the project, the structure is improved (or replaced) and the probability of structural failure for all events through year 20 is reduced to zero. Event damage equals the monetary damage if the structure fails multiplied by the probability that the structure will fail for this event. In this example, event damage is greater for the without-project condition than for the with-project condition for all events through year 20. Loss-probability curves are generated by plotting event damage for the without-and with-project conditions compared with the corresponding event probability, as in Figure 2. The area under a loss-probability curve equals the expected annual damage (EAD) from flooding. In this example, EAD is greater for the without-project condition than the with-project condition and the area between the two curves represents the benefits of the project.

The estimation of EAD requires significant hydrologic, hydraulic, engineering/geotechnical (if levees or other structures are involved) and economics data which must be analyzed to produce the loss-probability curves shown in Figure 2. EAD is the area under the loss-probability curves which requires integration. Computer models are available to assist with these calculations, which range in complexity from the US Army Corps of Engineers' HEC-Flood Damage Assessment which incorporates risk and uncertainty, as well as simpler spreadsheet tools such as the Flood Rapid Assessment Model (FRAM) developed for DWR and the Benefit Cost Analysis (BCA) software developed by FEMA for its own mitigation programs. These models are described in Chapter 5.

The expected annual benefit of the proposed project equals the difference between EAD without- and with- the project for *one* year. Table 3 illustrates how to determine the total present value of expected annual damage over the analysis period of the project. Continuing with the above example, EAD without the project is estimated to be $59,200 and with the project $42,000 (integrating the areas under the loss-probability curves shown in Figure 2); therefore the expected annual benefit is $17,200. This value is multiplied by the appropriate present value coefficient for the project's life cycle at a 6% discount rate (this example uses 15.76 which assumes a 50 year period) which results in a total present value of future benefits -- $271,100. If the total present value cost of future costs are $231,500 (including $200,000 in capital costs and $31,500 in operations & maintenance costs over the life of the project), then the net benefits are $39,600 and the B/C ratio 1.17.

Table 2: Example Event Damage

Hydrologic Event	Event Probability	Damage if Flood Structures Fail	Probability Structural Failure		Event Damage		Event Benefit (Million $)
			Without Project	With Project	Without Project	With Project	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
					(c) x (d)	(c) x (e)	(f) – (g)
10-Year	0.100	$200,000	0.50	0.00	$100,000	$0.0	$100,000
15-Year	0.067	$400,000	0.75	0.00	$300,000	$0.0	$300,000
20-Year	0.050	$600,000	1.00	0.00	$600,000	$0.0	$600,000
25-Year	0.040	$800,000	1.00	1.00	$800,000	$800,000	$0.00
50-Year	0.020	$1,000,000	1.00	1.00	$1,000,000	$1,000,000	$0.00

Figure 2: Example Loss-Probability Curves

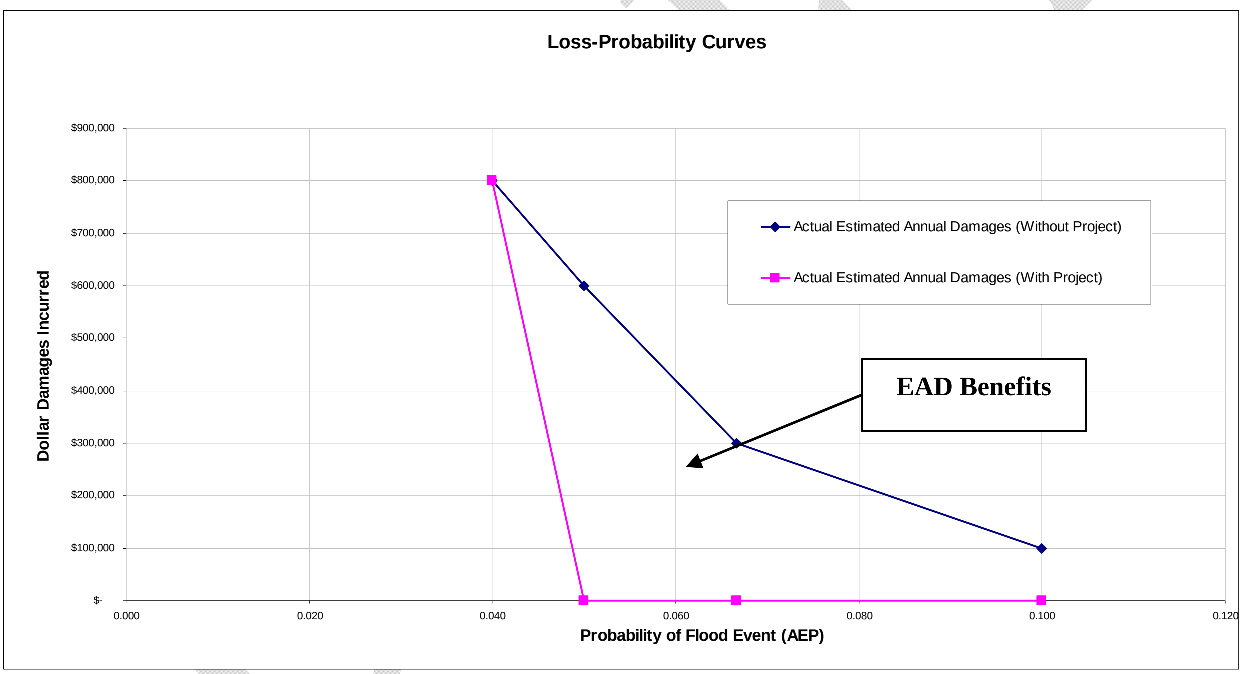


Table 3: Example Benefit/Cost Analysis

(a)	Expected Annual Damage Without Project (1)		$59,200
(b)	Expected Annual Damage With Project (1)		$42,000
(c)	Expected Annual Damage Benefit	(a) – (b)	$17,200
(d)	Present Value Coefficient (2)		15.76
(e)	Present Value of Future Benefits (3)	(c) x (d)	$271,100
(f)	Project Capital Costs		$200,000
(g)	Incremental Annual Project O&M Costs		$2,000
(h)	Present Value Coefficient (2)		15.76
(i)	Present Value Incremental Annual Project O&M Costs (2)	(g) x (h)	$31,500
(j)	Present Value Total Project Costs	(f) + (i)	$231,500
(k)	Present Value Net Benefits	(e) - (j)	$39,600
(l)	Benefit/Cost Ratio	(e) ÷ (j)	1.17

(1) Estimated from loss-probability curves in Figures 3; assumes no population growth thus EAD will be constant over analysis period.

(2) 6% discount rate; 50-year analysis period (could vary depending upon life of project).

Chapter 3: Federal Planning Accounts

Federal Principles and Guidelines

Given the complexity caused by the different perspectives that can be included in an economic analysis, an analysis framework, or "road map," can be very useful. Such a framework is provided in the US Water Resources Council, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, March 10, 1983 (P&G) which promulgates procedures for federal agencies involved in water and related land resources planning.[12] As its name implies, the *P&G* comprises two parts. The first part of the *P&G* sets forth principles "…intended to ensure proper and consistent planning by federal agencies in the formulation and evaluation of water and related land resources implementation studies." The second part of the *P&G* includes guidelines that "…establish standards and procedures for use by federal agencies in formulating and evaluating alternative plans for water and related land resources implementation studies."

The first section identifies four planning accounts which provide a framework for federal project evaluations:

- The national economic development (NED) account displays changes in the net value of the national output of goods and services expressed in monetary units; they are the direct benefits that accrue in the planning area and the rest of the nation. This account also includes the federal objective of water and related land resources project planning "… to contribute to national economic development (NED) consistent with protecting the nation's environment, pursuant to national environmental statues, applicable executive orders, and other federal planning requirements." Display of the NED account is required whereas display of the other accounts is discretionary.

[12] Federal agencies required to follow the *P&G* include the US Army Corps of Engineers, Bureau of Reclamation, Tennessee Valley Authority, and Soil Conservation Service (now called the Natural Resource Conservation Service). The *P&G* (plus related Corps planning guidelines) can be found at: http://www.usace.army.mil/cw/cecw-cp/library/planlib.html. FEMA follows the President's Office of Management and Budget, Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs, (October 29, 1992) http://www.whitehouse.gov/omb/circulars/index.html. The *P&G* are currently (2009) under review by the federal Council on Environmental Quality.

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- The environmental quality (EQ) account displays non-monetary effects on ecological, cultural, and aesthetic resources including the positive and adverse effects of ecosystem restoration plans.
- The regional economic development (RED) account displays changes in the distribution of regional direct and indirect economic activity (for example, income, and employment).
- The other social effects (OSE) account displays plan effects on social aspects such as community impacts, health, and safety, displacement, energy conservation, and other effects.

Key elements of the second section include more detailed discussions of federal planning standards (that is, how to implement the *P&G* process) as well as specific concepts and procedures for computing NED benefits that are typically expressed in monetary units, for example, municipal/industrial and agricultural water supply, urban and agricultural flood damage, power (hydropower), transportation (inland and deep draft navigation), recreation, and commercial fishing. The second section also discusses EQ evaluation concepts and procedures (for example, developing indicators that measure changes in the physical characteristics of plant and animal species but which are not usually assigned monetary values) as well as procedures for the RED and OSE accounts.

Although the *P&G* state that the national objective is NED, the USACE has recognized that water management planning must fully evaluate all four accounts: “Any alternative plan may be selected and recommended for implementation if it has, on balance, net beneficial effects after considering all plan effects, beneficial and adverse, in the four Principles and Guidelines evaluation accounts.”[13] This more comprehensive approach was made even more apparent following the devastation of Hurricane Katrina in 2005 along the Gulf Coast, which not only resulted in catastrophic damage to physical assets such as buildings and their contents, vehicles, infrastructure, etc., but also to the social structure and cohesion of entire communities. Unfortunately, analyzing information in some of these other accounts can be difficult (for

[13] USACE Engineering Circular EC 1105-2-409 *Planning in a Collaborative Environment,* May 31, 2005.

example, Other Social Effects), but efforts are underway by the USACE and others to describe the theoretical bases of these accounts and identify appropriate analytical methods. [14]

Table 4 provides an overview of the major types of effects that a flood risk management project might have and their relationship to the national economic development, regional economic development and other social effects planning accounts, which are discussed in more detail below. Information developed for the RED and OSE accounts should be included even if it is qualitative rather than quantitative.

Flood risk management projects also have significant implications within the environmental quality account, especially if they include ecosystem restoration objectives.[15] One of the key issues within the EQ account is how to evaluate the benefits of projects that provide ecosystem restoration benefits. This issue is discussed in more detail below in "Environmental Quality."

Updated Federal Principles and Guidelines

In the Water Resources Development Act of 2007, Congress instructed the Secretary of the Army to develop a new Principles and Guidelines for the U.S. Army Corps of Engineers. In an effort to modernize the approach to water resources development, the Obama Administration is expanding the scope of the Principals and Guidelines to cover all federal agencies that undertake water resource projects, not just the four agencies (i.e., U.S. Army Corps of Engineers, Bureau of Reclamation, Natural Resources Conservation Service and the Tennessee Valley Authority) which are subject to the current Principles and Guidelines. The revised P&G include several changes focusing upon:

- Achieving Co-Equal Goals
- Considering Monetary and Non-Monetary Benefits
- Avoiding the Unwise Use of Floodplains

[14] For example, see C. Mark Dunning and Susan Durden (USACE), "Theoretical Underpinnings of the Other Social Effects Account," September 2007.
[15] The USACE now formulates national ecosystem restoration (NER) or Combined NED/NER plans in addition to the traditional NED plans (flood risk management, water supply, navigation, etc.).

- Increasing Transparency and “Good Government” Results

In December 2009 the Administration sent the proposed *P&G* revisions to the National Academy of Sciences for their review and comment before the *P&G* are finalized.[16]

[16] For more information on the *P&G* update, visit the COE website at: http://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG

Table 4: Federal Planning Accounts

Flood Risk Evaluation Categories	Indicators	Units of Measure	National Economic Development					
			Plan Construction/ Operation			Flood Event		
			Direct	**Indirect/ Induced**	**Total**	**Direct**	**Indirect/ Induced**	**Total**
Physical Damage	▪ Buildings ▪ Contents ▪ Infrastructure ▪ Landscaping ▪ Site Contamination ▪ Vehicles ▪ Equipment ▪ Crops ▪ Ecosystems	$ EAD				X		
Loss-of-Functions	▪ NET loss of business net income ▪ NET loss of rental income ▪ NET lost wages ▪ NET loss of public services ▪ NET loss of utility services ▪ Displacement costs of temporary quarters ▪ Transportation system disruptions	$ EAD				X		
Other Floodplain Costs	▪ NFIP insurance program administrative costs ▪ Structure elevation/floodproofing costs	$ EAD				X		
Emergency Response	▪ Evacuation and rescue costs ▪ Security costs ▪ Dewatering, debris removal and cleanup costs ▪ Emergency flood management system repairs ▪ Humanitarian assistance	$ EAD				X		
Public Health & Safety	▪ Population at risk ▪ Casualties ▪ Displacement/shelter needs ▪ Critical facilities	People /event						
Other	▪ Property values ▪ Municipal fiscal impacts ▪ Community growth/cohesion ▪ Quality of life	Varies						

Table 4: Federal Planning Accounts (Continued)

Flood Risk Evaluation Categories	Indicators	Units of Measure	Regional Economic Development					
			Plan Construction/ Operation			Flood Event		
			Direct	Indirect/ Induced	Total	Direct	Indirect/ Induced	Total
Physical Damage	▪ Buildings ▪ Contents ▪ Infrastructure ▪ Landscaping ▪ Site Contamination ▪ Vehicles ▪ Equipment ▪ Crops ▪ Ecosystems	$ Event				X	X	X
Loss-of-Functions	▪ NET loss of business net income ▪ NET loss of rental income ▪ NET lost wages ▪ NET loss of public services ▪ NET loss of utility services ▪ Displacement costs of temporary quarters ▪ Transportation system disruptions	$/ jobs Event				X	X	X
Other Floodplain Costs	▪ NFIP insurance program administrative costs ▪ Structure elevation/floodproofing costs	$ Event				X	X	X
Emergency Response	▪ Evacuation and rescue costs ▪ Security costs ▪ Dewatering, debris removal and cleanup costs ▪ Emergency flood management system repairs ▪ Humanitarian assistance	$ Event				X	X	X
Public Health & Safety	▪ Population at risk ▪ Casualties ▪ Displacement/shelter needs ▪ Critical facilities	People Event				X		
Other	▪ Property values ▪ Municipal fiscal impacts ▪ Community growth/cohesion ▪ Quality of life	Varies	X	X	X	X	X	X

Table 4: Federal Planning Accounts (Continued)

Flood Risk Evaluation Categories	Indicators	Units of Measure	Other Social Effects: Plan Construction/ & Operation – Direct	Plan Construction/ & Operation – Indirect/ Induced	Plan Construction/ & Operation – Total	Flood Event – Direct	Flood Event – Indirect/ Induced	Flood Event – Total
Physical Damage	▪ Buildings ▪ Contents ▪ Infrastructure ▪ Landscaping ▪ Site Contamination ▪ Vehicles ▪ Equipment ▪ Crops ▪ Ecosystems	\$ Event						
Loss-of-Functions	▪ NET loss of business net income ▪ NET loss of rental income ▪ NET lost wages ▪ NET loss of public services ▪ NET loss of utility services ▪ Displacement costs of temporary quarters ▪ Transportation system disruptions	\$ Event						
Other Floodplain Costs	▪ NFIP insurance program administrative costs ▪ Structure elevation/floodproofing costs	\$ Event						
Emergency Response	▪ Evacuation and rescue costs ▪ Security costs ▪ Dewatering, debris removal and cleanup costs ▪ Emergency flood management system repairs ▪ Humanitarian assistance	\$ Event						
Public Health & Safety	▪ Population at risk ▪ Casualties ▪ Displacement/shelter needs ▪ Critical facilities	People Event	X			X		
Other	▪ Project construction ▪ Property values ▪ Municipal fiscal impacts ▪ Community growth/cohesion ▪ Quality of life	Varies	X			X		

National Economic Development

The national economic development (NED) account displays changes in the net value of the national output of goods and services expressed in monetary units, or NED benefits. These benefits are the benefits that accrue in the planning area and the rest of the nation and they typically include water supply, flood damage reduction, transportation, power, recreation, commercial fishing, etc, depending upon the project's objectives. NED benefits (and costs) provide the basis for conducting net benefit and/or benefit/cost analyses which demonstrate the economic justification of a project (i.e., maximum net benefits, B/C ratios > 1.00). Economic justification is an important component of determining a project's overall feasibility (engineering, environmental, financial, etc.).

Flood risk management projects can result in several different categories of NED benefits, including inundation reduction, intensification and location benefits. Inundation reduction benefits would apply to most flood risk management projects and these focus upon avoided physical damage, avoided loss-of-function costs, avoided "other" costs of using floodplains, and avoided emergency response costs as shown in Table 4. Intensification and location benefits would occur if the flood risk management project results in changes in future land use in the study area. However, the primary purpose of the NED plan is to protect existing development and not future development; therefore plans formulated to produce primarily land development opportunities do not reduce actual flood damage and therefore will not be funded by the USACE [17] or by the State.

NED inundation reduction benefits are usually expressed in monetary terms and on an annualized basis (expected annual damage). These benefits include (Table 4):

- *Avoided physical damage*. This category (also known as direct flood damage) is typically the most straight-forward to estimate. Structures, contents, infrastructure (transportation systems, utilities, schools, hospitals, etc.), landscaping, vehicles, equipment and crops can be damaged by flood events. The monetary damage is the cost to repair or value the damaged property. If direct damage estimates are not available, then depth/damage curves can be used to estimate damage, at least for structures and their contents. This

[17] USACE, Amendment 1 of Appendix E to ER 1105-2-100; USACE *National Economic Development Manual*.

approach first requires estimating a structure's value. Structures that are potentially inundated with flood water must be valued using depreciated replacement cost and not full replacement costs.

- *Avoided loss-of-function costs*. These costs occur when facilities are damaged thereby disrupting their normal functions. For example, occupants of residential, commercial or public buildings may incur displacement costs for temporary quarters when flood damage makes buildings unsafe for occupation. Other costs include loss of business net income, loss of rental income, loss of wages, disruption time and deterioration in the overall "quality of life."[18] In addition, loss-of-function for some types of critical facilities may have negative impacts on the community as a whole. These types of impacts would include the loss of public facilities (e.g., schools, hospitals, police/fire stations, nursing homes), transportation systems (e.g., highways, airports, ports) and utilities (e.g., water, sewer, electricity).

- *Avoided "other" costs of floodplains*. Occupants of floodplains incur other costs that may be reduced or eliminated if a proposed project is implemented. For example, flood proofing or structure elevation costs may be avoided with a project if it can be demonstrated that these costs would be incurred without the project. Although a project may also eliminate the requirement for NFIP flood insurance, the only benefit that can be claimed is the administrative cost of the program, currently estimated to be about $192 per policy.[19]

- *Avoided emergency management costs*. These costs include a wide range of disaster response and recovery costs that may be incurred by a community during and immediately following a flood. Examples include avoided emergency operations costs

[18] Care must be taken estimating the loss of business net income and lost wages because the lost business net income of the flooded enterprise may be made up by other competitors in the region or even the State. Workers who have lost their jobs can be assumed to be mobile and locate jobs elsewhere, granted with a temporary displacement period. In practical terms, the only time that lost net business net income would be included is if it (a) had a comparative advantage over other firms producing the same products or services, thus other firms could only replace the lost output at a greater cost, or (b) the flooded firm produces unique products and services not produced elsewhere.

[19] USACE *Planning Guidance Notebook*, ER 1105-2-100, April 22, 2000, Appendix E, pg. E-100; dollar values of NFIP administrative costs can be found at http://www.usace.army.mil/cw/cecw-cp/library/egms/egms.html

(e.g., personnel and equipment mobilization, materials purchases), evacuation and rescue costs, debris removal/cleanup, temporary security costs and emergency repairs to flood management systems (such as levees, floodwalls, etc.).

NED Costs. Project costs generally can be classified as either capital or annual operating costs. All costs necessary to obtain project benefits over the analysis period must be included in the cost analysis, including:

- Capital costs. Capital costs are all expenditures necessary to complete the project so operations can commence. Capital costs (for example, construction, "fixed" or "first" costs) include expenditures for planning and design, land, structures, materials, equipment, and labor, as well as allowances for contingencies. Financial costs (such as interest during construction and long-term debt service interest) are not included as a capital cost, although they are important in a financial analysis. If most capital costs occur in one year, then these would be included in the "base year' for the net benefit analysis. If capital costs are spread over several years (most likely), then the future value of these costs must be determined; see Table 3 for an example.
- Operation and maintenance costs. O&M costs include the project's annual administrative, maintenance, energy and replacement costs and they are often called "variable costs" because they vary with different levels of project output. For example, levees require annual inspection and maintenance activities. These types of costs can vary significantly over the lives of different flood management projects and thus have important implications for the project's sustainability. Identify without- and with-project O&M costs.
- Externalities. Often the activities of producers or consumers have effects upon others that impose costs (or sometimes benefits) for which no compensation is received. For example, a new levee in community A may increase river stages downstream in community B, which subsequently results in more flood damage in community B. The economic analysis, which is performed to justify the new levee in community A, should also take into account the cost increases for community B. Unfortunately, many externalities are difficult to identify, quantify, and ultimately, assign monetary values. But qualitative descriptions of these costs must be included at a minimum.

- "Opportunity" costs. Opportunity cost is the productivity forgone by not investing in the next optimal project. The value of the sacrificed productivity is determined by the monetary value placed on the output of the alternative project. For an economic analysis, it is often difficult to determine what these opportunity values are, so purchase costs usually are used as a "proxy." [20]

The USACE has prepared a new *NED Flood Damage Reduction Manual* that provides an excellent discussion of the *P&G* urban flood damage reduction procedures in the context of how these procedures are generally accomplished today.[21] These procedures should be followed for DWR urban flood risk management programs. Procedures for estimating crop flood damage reduction benefits can be found in the *P&G* or in the Corps' *Planning Guidance Notebook*.[22]

Chapter 6 presents example tables that can be used to display the assumptions data and NED analysis results. Although these tables present a recommended way of presenting this type of information, they are not required if the information is provided in other formats.

[20] An example of a flood-related opportunity cost is if a levee is being reconstructed and the potential exists for a levee setback which could result in ecosystem restoration benefits, but the setback is not considered in the feasibility analyses. The "opportunity" of creating ecosystem benefits is then lost, at least for many years.

[21] http://www.iwr.usace.army.mil/ned/

[22] http://www.usace.army.mil/cw/cecw-cp/library/planlib.html

Regional Economic Development

Although the identification and measurement of direct flood risk management benefits and costs using NED net benefits and/or benefit/cost ratios are the key metrics used to demonstrate the economic justification of proposed projects, by themselves they do not tell the "complete story." Floods can also result in significant regional economic and other social disruptions to a community, as demonstrated by the devastating effects of Hurricane Katrina upon New Orleans and the Gulf Coast. In the Gulf Region, many neighborhoods and even entire communities may never fully recover from that devastating storm. Thus, to the extent these types of socioeconomic effects can be understood and assessed, the decision-making process can be much better informed.[23] Although quantification of many of these effects can be very complex, it is recommended that at minimum they be qualitatively assessed.

Floods can have significant regional economic effects (including income and employment) outside of those directly affected within floodplains; these effects can occur within entire counties, watersheds, or even the State. Thus, the RED account shows the effects of project alternatives on the distribution of regional economic activity *in the area where the plan will have significant income and employment effects*.[24] Regional income effects include the direct NED effects plus income transfers to and from the region. Income transfers include project implementation outlays; transfers of economic activities from other regions that have been attracted by improved flood protection; indirect and induced effects; humanitarian assistance, NFIP insurance payments and any State liability payments following a flood event. The effects of a project upon regional employment usually parallel those on regional

Direct, Indirect and Induced Economic Effects

Direct effects: changes in output, income and employment of a given industry resulting from changes in final demand.
Indirect effects: changes in output, income and employment of a given industry resulting from the iterations of industries purchasing from other industries caused by the direct economic effects.
Induced effects: changes in output, income and employment caused by household expenditures generated by direct and indirect economic effects.

[23]In addition to project feasibility analyses, information developed for the regional economic and social effects analyses can also inform a community's flood emergency planning programs.
[24] This area of "significant" economic effects may be difficult to delineate but a practicable solution may be to define this area on a county basis.

income. Typically regional economic analyses are conducted using input-output (I-O) models which measure the flow of commodities and services among industries, institutions and final consumers in an economy.

For flood risk management analyses, regional changes in output, income and employment can be measured for economic effects caused by project construction as well as the effect of a flood event upon a regional economy. In general, project construction activities would have a temporary beneficial impact on a regional economy whereas flood events would have an adverse effect because structural inundation would result in declines in business production over long periods. Specific types of effects include:

- Construction
  - Construction expenditures and labor requirements and
  - Effects upon other sectors (recreation, agriculture, etc.)
- Flood events
  - Reduction in business net income within flood zone,
  - Increase in business net income outside of flood zone as residents and businesses respond to the flood emergency within their community,
  - Changes in agricultural production,
  - Emergency services,
  - Humanitarian assistance/insurance payments,
  - Loss in property values,
  - Transportation effects, and
  - Fiscal impacts (property and sales tax revenues, public services such as schools, police and fire protection, etc.) within communities.

There is an overlap between NED and RED benefits, *thus the two are not addictive*. In addition, NED benefits are usually estimated for several flood events but then annualized for inclusion in net benefit or benefit/cost ratio calculations. RED benefits are typically described on a *per event* basis.

Chapter 6 presents example tables that can be used to display RED analysis results. Although these tables present a recommended way of presenting this type of information, they are not required if the information is provided in other formats.

Other Social Effects

According to the *P&G*, the OSE planning account should "display plan effects on social aspects such as community impacts, health and safety, displacement, energy conservation and others." As with the RED analysis, the OSE analysis includes effects caused by project construction as well as the effects of a flood event upon communities. Construction effects can include both temporary and permanent effects caused by construction activities and by the potential relocation of residents and businesses within the project "footprint." Flood events can also include temporary and permanent effects, depending upon the community's ability to recover from the flood event. Some types of effects that should be analyzed include:

- Construction
    - Public health and safety
    - Displacement
    - Community growth/cohesion
- Flood events
    - Public health and safety
    - Displacement
    - Shelter needs
    - Casualties
    - Saturation of flood insurance within communities[25]
    - Community growth/cohesion
    - Quality of life

In addition to the extent and depth of flooding, other factors that can significantly affect the OSE analysis include:

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[25] The ability of a community to recover from a flood event can be enhanced if significant numbers of property owners have purchased flood insurance.

- Warning times
- Timeline of flood events (how many acres/structures are inundated after 6, 12, 24, 48, etc. hours?
- Duration of flooding
- Duration of recovery/rebuilding efforts

Chapter 6 presents example tables that can be used to display the assumption data and RED/ OSE analysis results. Although these tables present a recommended way of presenting this type of information, they are not required if the information is provided in other formats.

Environmental Quality

Water resource management projects and programs are becoming multi-objective, and often one of those objectives is ecosystem restoration. For most objectives, monetary benefits can be reasonably estimated (for example, water supply and quality, hydropower, flood damage reduction, recreation). However, for ecosystem restoration, the economic evaluation is much more difficult. Should monetary benefits be assigned to ecosystem resources? Ecosystems perform a multitude of complex and interrelated functions that not only provide basic biological support but also provide valuable goods and services to society (for example, enhanced water supply and quality, flood damage reduction, recreation). If these goods and services can be identified and measured, then it may be possible to place monetary values on them using market or non-market valuation methods[26]. However, if these ecosystem goods and services are monetized, the resulting values should not be interpreted as the total value of the ecosystem but rather of the particular services it provides for society.

Ecosystem evaluation methods are discussed in the DWR *Economic Analysis Guidebook*, Chapter 4. Two flood management example analyses are presented in the Appendix B that illustrate different ways of evaluating ecosystem benefits in an economic analysis.[27] The Hamilton City Flood Damage Reduction and Ecosystem Restoration feasibility study follows USACE planning guidance by utilizing cost-effectiveness/ incremental cost analysis to evaluate

[26] Identifying ecosystem goods and services requires the measurement and quantification of ecosystem outputs, which is, by itself, a major challenge in which there is not unanimity of opinion among environmental scientists on how to accomplish.
[27] Websiste: http://www.economics.water.ca.gov/guidance.cfm.

ecosystem benefits—basically, determining which ecosystem alternative gives the “most bang for the buck” and combining this information (through a trade-off analysis) with flood damage reduction benefits of the proposed project. This method requires a cost allocation of the project costs between flood damage reduction and ecosystem restoration (or other project purposes), often using the separable cost-remaining benefits (SCRB) method. After the cost allocation, project costs allocated to flood damage reduction can be compared to flood damage reduction benefits, ecosystem restoration costs can be compared to ecosystem restoration benefits (or physical outputs), etc. In contrast, the Colusa Basin Drainage District Integrated Watershed Management Study places monetary values on ecosystem benefits, which are then directly incorporated into a benefit-cost analysis along with flood damage reduction benefits. However, this type of analysis would not be acceptable to the USACE.

Chapter 4: Other Planning Considerations

Intensity of Analysis

To perform economic analyses of flood risk management projects, the following types of data are required:

- Hydrologic: analysis of the frequency, location and amount of runoff throughout a study area,
- Hydraulics: analysis of stream water surface profiles, flood inundation boundaries, and other stream flow characteristics (for example, stage-frequency),
- Geotechnical: analysis of levee failure including development of levee fragility curves based upon different levee failure causes,
- Economics: identification of population, structural and other physical assets at risk, development of stage-damage functions and estimation of expected annual damage and project performance statistics.

The quality of the economic analysis (data, methods and models) needs to be commensurate with the cost of the project and with the proximity of the benefit-cost ratio to 1.0. In other words, if a multi-million dollar project is being proposed and the benefit-cost ratio is close to 1.0, then the "best available" data, methods and models must be used. For agencies also seeking USACE funding and/or levee certification, it is strongly recommended that "risk analysis" be conducted.

Risk Analysis

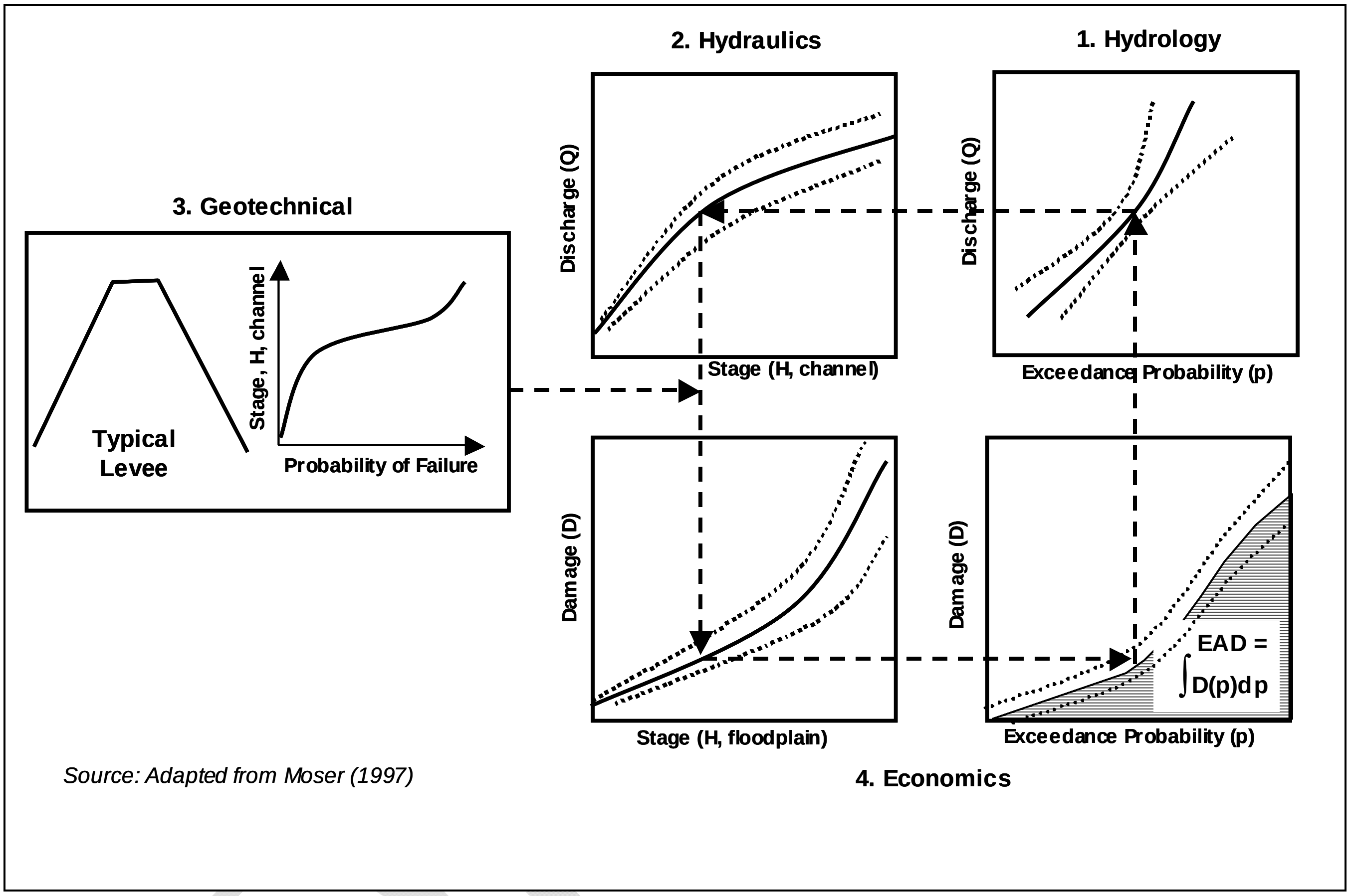
The USACE requires that "risk analysis" be conducted for all of its flood damage reduction studies (ER 1105-2-101). "Risk analysis" is an evaluation and decision making approach that explicitly, and to the extent practical, analytically incorporates considerations of risk and uncertainty in a flood damage study. The goal of "risk analysis" is a comprehensive approach in which the values of all key variables, parameters, and components of flood damage reduction studies are subject to probabilistic analysis (hydrology, hydraulics, geotechnical and economics).

The USACE software HEC-FDA (Flood Damage Assessment) incorporates risk-based analysis by quantifying uncertainties in the hydraulics, geotechnical, and economics data using Monte Carlo simulation. The two primary outputs from HEC-FDA include expected annual damage estimates and project performance statistics. Expected annual flood damage is the average of all possible damage values, taking into account all expected flood events and associated hydrologic, hydraulic, geotechnical, and economic uncertainties. Project performance statistics describe the hydraulic performance of a plan incorporating geotechnical levee failure assumptions. These include **expected annual exceedance probability** (the annual probability of having a damaging flood event in a given year, such as a levee failure), **long-term risk** (the chance of having one or more damaging events over a period of time, similar to the question: what's the chance my house could be flooded during my 30 year mortgage?), and **conditional non-exceedance probability (**the probability of containing specific flood events and avoiding damage). Figure 3 illustrates the conceptual components of a HEC-FDA risk-analysis. HEC-FDA is available at: http://www.hec.usace.army.mil/software/hec-fda/hecfda-hecfda.html

For agencies seeking USACE funding and/or levee certification, it is strongly recommended that "risk analyses" be conducted. USACE guidance on "risk analysis" can be found in:

- EM 1110-2-1619, *Risk-Based Analysis for Flood Damage Reduction Studies*, August, 1996 and
- ER 1105-2-101, *Risk Analysis for Flood Damage Reduction Studies*, January 2006.

Figure 3: Conceptual USACE Risk and Uncertainty Approach for Estimating Flood Damage



Levels of Protection

Flood risk management projects are often characterized as having a certain "level of protection" (for example, 100- or 200- year). Often these labels are misleading because of (a) the inherent uncertainties in their estimation, (b) the wrong connotations they sometimes give to the public (i.e., a 100-year flood will only occur once every 100 years), and (c) they ignore residual risk. However, despite these limitations, it is still necessary to report levels of protection (without- and with-project) using consistent methods.

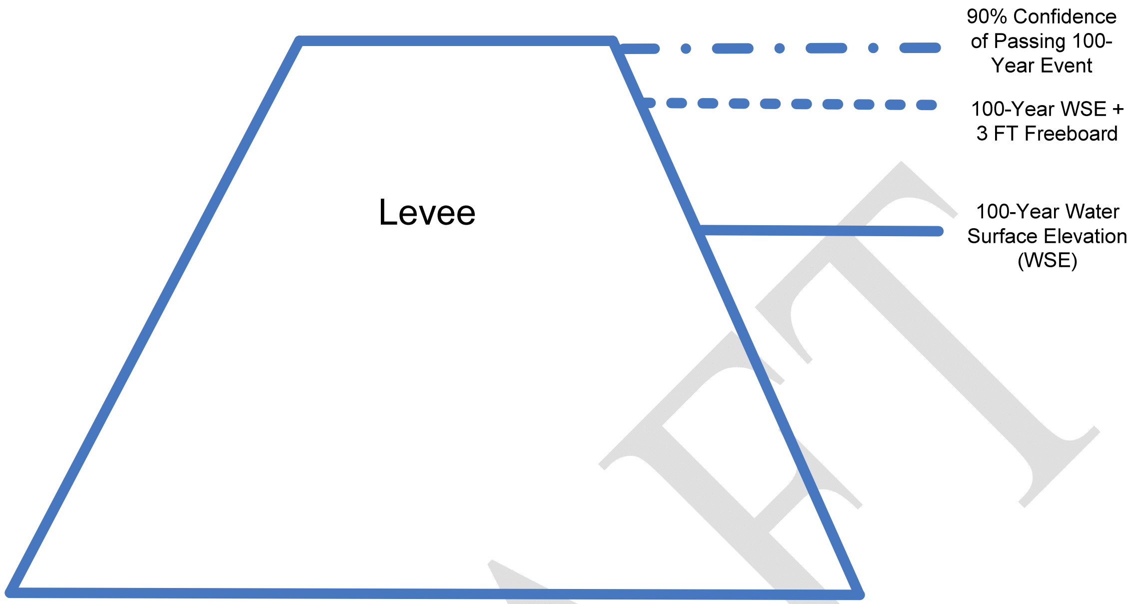
The two primary methods of measuring levels of protection include:

- Deterministic method: this method relies on defining a potential water surface elevation for a specific frequency flow event and then applying a specific freeboard on top of this water surface elevation to account for uncertainty. Often the freeboard is three feet, but it can be higher depending on local conditions. The water surface elevation would be determined by traditional hydrologic, hydraulic and related methods. No uncertainty in these parameters would be considered.
- Probabilistic method: directly incorporates "risk-based" analysis, usually using the HEC-FDA model and the project performance statistics; uncertainty in each of the major physical parameters is considered. The USACE uses the conditional non-exceedence statistic to certify to FEMA that levees and other flood structures meet the 100-year standard (i.e., it must be shown that there is at least a 90% confidence of passing the 100-year event).[28]

Figure 4 illustrates the differences between these approaches for a levee project being designed to provide 100-year level of protection (note: the probabilistic method may result in a levee height that is greater, lesser or equal to that determined by the deterministic method).

[28] For more information on levee certification issues, see the DWR *Quick Guide* at http://www.fpm.water.ca.gov/docs/CAQG-screen.pdf

Figure 4: Deterministic vs. Probabilistic Methods for Evaluating Level of Protection



Residual Risk

Residual risk is the flood risk that remains if a proposed flood risk reduction project is implemented. Residual risk includes the consequences of capacity exceedence or project failure prior to capacity exceedence. Often residual risk can be catastrophic. Thus, even though an expected annual damage assessment may indicate positive net benefits, applicants must evaluate residual risk which can assist their flood emergency planning.

There are a couple of different ways to evaluate residual risk. The first is through the expected annual damage computation. For example, if the without-project EAD is $500,000 and the with-project EAD is $300,000, then the project has reduced EAD by $200,000 (i.e., project benefits) but $300,000 in EAD remains with project. This is a measure of residual risk and it takes into account both the probabilities and consequences of flooding without- and with-project, but unfortunately it tends to mask the potentially catastrophic effects if project failure or exceedence occurs because it is annualized.[29] Knowledge of these potentially catastrophic effects is critical for flood emergency planning purposes (what will be the extent of such a flood event, how deep, how fast it will spread, how many people affected, for how long, etc.).

Another way to evaluate residual risk is to focus upon floodplains of specific events, especially the largest floodplain expected to be “protected” by the project because the community may have a fall sense of security with the project in place. In reality, residents within this protected floodplain are still at risk, albeit with a smaller probability of flooding. Thus, for the largest floodplain protected by the project, information should be developed describing the socioeconomic activities at risk (much of this information is developed in the RED and OSE accounts), including:

- Magnitude of flooding (extent, depth, velocity, evacuation times, and speed and duration of flooding),
- Population at risk (including high-risk groups such as low income, handicapped, elderly, etc.),

[29] As discussed above, risk is defined as Probabilities X Consequences where probability includes the frequency of the flood event and structure failure, and consequences are the effects of the flood water upon the human and natural environments.

- Community infrastructure at risk (such as hospitals, emergency response facilities, schools, utilities, transportation facilities, military facilities, etc.) and
- Major employment centers at risk.

Focusing upon the assets at risk within a specific floodplain ignores the probabilities of flooding, but these can be incorporated into the analysis. For example, if the largest floodplain to be protected by a project is the 200-year floodplain, then the annual probability of flooding for this floodplain is 0.005. If a project is constructed, then the residents in this floodplain are still at risk, but with a reduced annual probability of flooding (for example, 0.003).

Partial Projects

A major problem in analyzing flood damage reduction benefits occurs when a community is surrounded by a levee *system* comprised of multiple levee segments. Although intuitively it would seem that repairing one segment should result in at least some incremental benefit to a community, it is difficult to quantitatively estimate this incremental benefit taking into account remaining deficiencies in the levee system.

A procedure is available to estimate the incremental benefits of repairing individual segments of a levee system using the Corps' HEC-FDA model. This procedure estimates the annual exceedence probability (AEP) and expected annual damage (EAD) for each levee segment for the without-project condition and then estimates a weighted EAD using AEP as the weighting factor. These steps are repeated again for the with-project condition, taking into account changes in the levee failure assumptions attributable to the proposed levee segment improvements. The difference between the weighted EAD for the without-project condition compared to the with-project condition is the benefit of the levee segment improvements. However, this procedure will only work if the levee segments are *independent* of each other; i.e., they have discrete hydraulic and/or levee failure characteristics. If not, this procedure will not be applicable.

Thus, this procedure typically works best if:

a. The communities are protected on two or more sides by levees on different streams,
b. These streams have different hydraulic characteristics (i.e., water surface profiles),
c. Each stream has differing hydraulic characteristics "upstream" vs. "downstream," and/or

d. The levee segments have different physical characteristics due to construction and/or maintenance practices.

If a community is only protected on one side by a levee system but is proposing multiple levee “fixes,” this procedure should still be applicable if for each fix if (c) and/or (d) are present.

David Ford Consulting Engineers, Inc. applied this DWR-approved methodology to estimate the incremental benefits of alternative levee segment improvement plans for the Plumas Lakes area which is subject to flooding from multiple water sources, including the Yuba River to the north, Feather River to the west, Bear River to the south and the Western Pacific Interceptor Canal to the east.[30] Appendix I includes an excerpt from David Ford’s report describing how this procedure was applied for the Plumas Lakes area.

[30] David Ford Consulting Engineers, Inc., *Report on Alternatives Analysis—Phase IV: Feather River Levee Repair Project (Appendix VI)*, Three Rivers Levee Improvement Authority, December 2006.

Future Growth

A critical task within an economic analysis is defining without project conditions, and over a 50-year analysis period, these conditions are likely to include population growth, especially in the rapidly urbanizing areas of the Central Valley. However, DWR requires that an economic analysis must first demonstrate that the net benefits of a proposed flood risk management project are positive with existing development before including population growth. If planned population growth is included in the without project condition, it must be assumed that the community has or will adopt floodplain regulations pursuant to the National Flood Insurance Program that prohibit development in the 100-year floodplain unless its elevated or flood proofed (for commercial structures).

If future growth would not occur without the project but would occur with the project, then the project is *inducing growth*. Benefits associated with land use changes can be measured and are called "location" benefits. However, DWR will not fund flood risk management projects providing primarily future land development opportunities, therefore "location" benefits will be excluded.

Projects with Multiple Funding Sources

The economic analysis must include the total costs of the project, regardless of funding sources. All project costs--capital and operations and maintenance (O&M)--must be included even if State or other funding is available.

Use of Prior Analyses

The use of prior analyses (reconnaissance or feasibility studies, benefit/cost analyses, etc.) is permitted as long as that analysis and supporting data are not older than five years, unless approved by the DWR Economic Analysis Section. Benefit and cost data must be updated to the current year using appropriate cost indices.

Chapter 5: Models

US Army Corps of Engineers

HEC-FDA

Developed by the USACE' Hydrologic Engineering Center (HEC) in Davis, CA, Flood Damage Analysis (FDA) is the USACE's primary flood damage reduction model which integrates hydrologic, hydraulic, and geotechnical engineering and economic data for the formulation and evaluation of flood damage reduction plans. The program incorporates risk-based analysis by quantifying uncertainties in the hydraulics, geotechnical, and economics data using Monte Carlo simulation. The two primary outputs from HEC-FDA include expected annual damage estimates and project performance statistics. Expected annual flood damage is the average of all possible damage values, taking into account all expected flood events and associated hydrologic, hydraulic, geotechnical, and economic uncertainties. Project performance statistics describe the hydraulic performance of a plan incorporating geotechnical levee failure assumptions. These include **expected annual exceedance probability** (the annual probability of having a damaging flood event in a given year, such as a levee failure), **long-term risk** (the chance of having one or more damaging events over a period of time, similar to the question: what's the chance my house could be flooded during my 30 year mortgage?), and **conditional non-exceedance probability (**the probability of containing specific flood events and avoiding damage). Figure 5 illustrates the conceptual components of a HEC-FDA analysis. HEC-FDA is available at: http://www.hec.usace.army.mil/

Advantages of using HEC-FDA include:

- This is the software that is used by the USACE, thus if DWR or other agencies are seeking federal cost sharing, analyses should be more compatible,
- Uncertainty is directly incorporated into the analysis utilizing Monte Carlo simulation which explicitly accounts for uncertainty in key functions (discharge-exceedence, stage-discharge and stage-damage),
- Levee failure assumptions (for water surface elevations below top-of-levee) can be entered into the analysis,

- It can estimate most direct flood damage losses (for example, single-family residential, multi-family residential, commercial, industrial, etc.),
- Although designed for urban flood damage analyses, can be adapted for agricultural analyses,
- Structural inventories can be directly input into the software and it will develop the stage-damage functions, or stage-damage functions can be developed outside of the software and then directly input into it,
- Project performance statistics (annual exceedence probability, long-term risk and conditional non-exceedence) are output which can be used for determining "levels of protection" and levee certification purposes, and it's
- Very useful for plan formulation purposes.

Disadvantages of using HEC-FDA include:

- Typically can not be run "off the shelf" without training,
- Extremely data intensive; requires hydrologic, hydraulics, geotechnical (if levees are present), and economics data,
- Not GIS-based, but GIS can be used to develop data inputs (such as structural inventories),
- Not applicable for coastal analyses, and
- It does not estimate indirect or regional impacts (income, employment, etc.).

HEC-FIA

HEC is developing Flood Impact Analysis (HEC-FIA) to estimate flood *event* direct urban and agricultural damage and loss of life. Although EAD estimates will not be developed by HEC-FIA, event damage estimates can be input into HEC-FDA and other models to do the integration analyses required for the EAD estimates.

Federal Emergency Management Agency

HAZUS-MH (Multi Hazard)

FEMA has developed this GIS-based US multi-hazard assessment software which contains a Flood Loss Estimation Model that includes flood hazard analysis and flood loss estimation modules for riverine and coastal analyses.[31] The flood hazard analysis module uses characteristics such as frequency, discharge, and ground elevation to estimate flood depth, flood elevation, and flow velocity. The loss estimation module estimates direct and indirect economic losses using the results of the flood hazard analysis and structural inventories. These losses include structural and contents damage and loss of functions to general building stock (residential, commercial, industrial, etc.), essential facilities (emergency centers, medical care centers, schools, etc.), transportation systems (highways, rails, airports, bus, etc.), utilities (potable water, waste water, electrical, communications, etc.), and agricultural products. Impacts to population, especially groups of special concern (low income, ethnicity, age groups over 65, etc.), and shelter requirements are also estimated. In addition to the Flood Loss Module, HAZUS-MH also contains earthquake and hurricane wind assessment models. HAZUS-MH analyses can be conducted at different levels of rigor. A Level 1 analysis utilizes default hydrologic, hydraulics and economic inventory information; Level 2 and 3 analyses incorporate user-input local data to improve accuracy of analyses. HAZUS information is available at **http://www.fema.gov/plan/prevent/hazus/index.shtm**

Advantages of using HAZUS-MH include:

- It is GIS-based, which greatly facilitates analyses and displaying results,
- It can be adapted to different analysis "levels" depending upon user-input data; default values are available for "reconnaissance" studies,
- The availability of default values allows for analyses which otherwise could not be conducted because of the lack of local data,
- It can be used for riverine and coastal flood analyses,

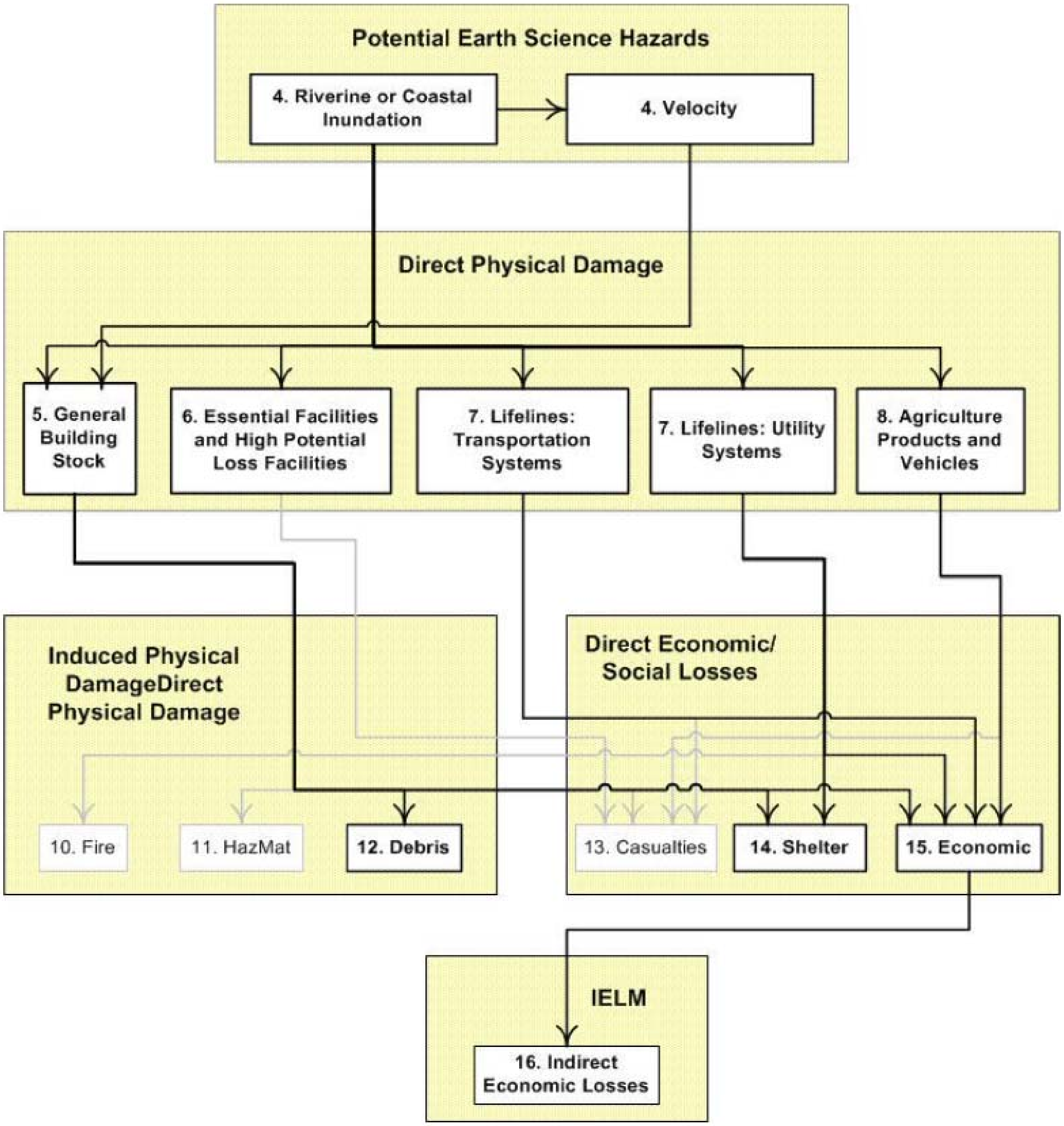
[31] HAZUS-MH Version MR4 is currently available.

- It can estimate direct flood damage losses as well as indirect regional impacts (income, employment, casualties, etc.) and
- It is often used by communities in preparing their FEMA-required local hazard mitigation plans.
- Disadvantages of using HAZUS-MH include:
- Because it is GIS-based, HAZUS-MH requires ArcGIS software and expertise,
- It does not directly incorporate uncertainty, although this can be alleviated by sensitivity analyses,
- It does not provide a rigorous analyses of levees, although a levee can be "drawn" into the study area and a "level of protection" assigned to it,[32] and
- Project performance statistics are not estimated.

Figure 5 presents a schematic overview of HAZUS.

[32] The next version of HAZUS (fall 2008) may incorporate levee failure analysis.

Figure 5: HAZUS Flood Model Overview



Mitigation BCA Toolkit

FEMA has developed new BCA Software (version 4.5.5; August 2009) to perform benefit-cost analyses for floods, hurricane winds, earthquakes, tornados, wild fires, and a “generic” damage frequency assessment. FEMA developed the BCA software for specific use by local and state agencies applying for funding in several mitigation grant programs. The software is menu-driven and leads the user through several screens in which data pertinent to the costs and benefits (depending upon the hazard being studied) are entered. Default data is provided for many variables (for example, the contents percentage of structures) although local data can be input into the model. The software then computes net benefits and the B/C ratio. The software comes with extensive on-line resources, including a Recourse Kit and training, and is available at http://www.bchelpline.com/

Advantages of using the BCA Software include:

- It can be used for riverine and coastal flood analyses,
- It can estimate direct flood damage losses (including physical damage, loss of functions, and emergency management costs),
- It is used by communities in preparing their FEMA-required local hazard mitigation plans so locally prepared models may already be available,
- It is menu-driven and therefore relatively easy to use,
- Separate modules store project and structural inventory data so multiple projects with different data sets (for example, structural inventories) can be analyzed, and
- It estimates costs and benefits.

Disadvantages of using BCA Software include:

- It does not directly incorporate uncertainty, although this can be alleviated by sensitivity analyses,
- It does not allow for rigorous analyses of levees, although a levee can be included and a “level of protection” assigned to it,
- Regional impacts (income, employment, casualties, etc.) are not estimated,

- Project performance statistics are not estimated, and
- The discount factor is fixed at 7% which FEMA uses and it can not be changed.

California Department of Water Resources

Flood Rapid Assessment Methodology (FloodRAM)

Consultants to DWR have developed a spreadsheet model to estimate flood damage. This model develops loss-probability curves for without- and with-project conditions (see Figure 3) based upon hydrologic and hydraulics data, probability of levee failure data, structural and crop inventories, depth-damage curves, etc. Damage categories include residential, commercial and industrial properties, crops and roads, but other categories can be added. An adjustment (for example, 25%) is added to damage estimates to account for indirect damage not specifically included in the model. The model is flexible in that many of the analysis assumptions and parameters can be changed (for example, structural foundation heights, unit replacement values, and depreciation factors; depth-damage curves; discount rates; analysis period; other indirect damage "adjustment factor"; etc.). Like all other models, the quality of the Flood RAM analyses is directly dependent upon the quality of the input data (for example, floodplain extents and depths, structural inventories, etc.). FloodRAM is available from DWR economics staff.

Advantages of using Flood RAM include:

- It can provide relatively quick estimates of EAD depending upon the availability of input data,
- It can be adapted to different analysis "levels" depending upon the quality of the input data,
- It incorporates probability of levee failure,
- It can be used for riverine analyses but could be applicable to coastal analyses, and
- Users can easily see data inputs and calculations (i.e., it is "transparent").

Disadvantages of using FloodRAM include:

- It does not directly incorporate uncertainty, although this can be alleviated by sensitivity analyses,
- It does not estimate regional impacts (income, employment, casualties, etc.), and

- Project performance statistics are not estimated (although FloodRAM inputs and model outputs can be input into HEC-FDA to obtain project performance statistics).

Table 5 compares key characteristics of the flood risk management models.

Table 5: Characteristics of Flood Risk Management Models

Characteristics	**Models**				
	HEC-FDA	**HEC-FIA**	**HAZUS MH**	**BCA Toolkit**	**FloodRAM**
Sponsoring Agency	USACE	USACE	FEMA	FEMA	DWR
Model Outputs					
Event Damage	YES	YES	YES	YES	YES
Expected Annual Damage	YES	NO	YES	YES	YES
Project Performance Stats	YES	NO	NO	NO	NO
Casualties	NO	YES	NO (4)	NO	NO
Type of Damage					
Direct (1)	YES	YES	YES	YES	YES
Indirect (2)	NO	NO	YES	NO	NO
Levee Failure Analysis	Fragility Curves	Fragility Curves	Assumed LOP (3)	Assumed LOP (3)	Assumed Failure Probability
Uncertainty	YES	NO	NO	NO	NO

(1) Includes physical damage, loss of functions, other costs of floodplain, and emergency management costs.

(2) Regional income and employment effects.

(3) Level of protection (e.g., “100-year”)

(4) HAZUS does estimate casualties in the earthquake and hurricane wind modules.

Chapter 6: Information Displays

The following example tables (labeled EX--__) illustrate the types of information that should be presented in a flood risk management economic analysis, although other formats may be used provided similar information is displayed. Information in these tables should be shown for existing, base year conditions (if different than existing conditions) and for projected conditions if included in the analysis. Most of these tables require information for *flood events*. Recommended analysis events include the 25-, 50-, 100-, 200-, and 500-year events, but other events may be used depending upon study circumstances.

Historical Flood Events and Effects

Provide qualitative/quantitative descriptions of historical flood events, including:

- Sources of flooding,
- Estimated event frequency,
- Extent, depth and durations of inundated areas,
- Performance of existing flood management facilities,
- Estimated flood damage, including physical damage to structures and contents, vehicles, etc.; loss of functions; and emergency management costs;
- Impacts upon population (especially at risk groups such as low income, handicapped and the elderly),
- Impacts upon regional employment and income, and
- Estimated casualties (numbers of deaths, injuries and illnesses.

Table EX-1 can be used to display historical flood damage, which should be expressed in current year (2007) dollar values using the Gross Domestic Product Implicit Price Deflator.

Table EX-1: Historical Flood Damage

Event Year	Estimated Event Frequency	Flood Depths	Flood Duration	Flood Damage (1)

(1) Flood damage includes physical damage (structures and contents, vehicles, etc), loss of functions, and emergency management costs.

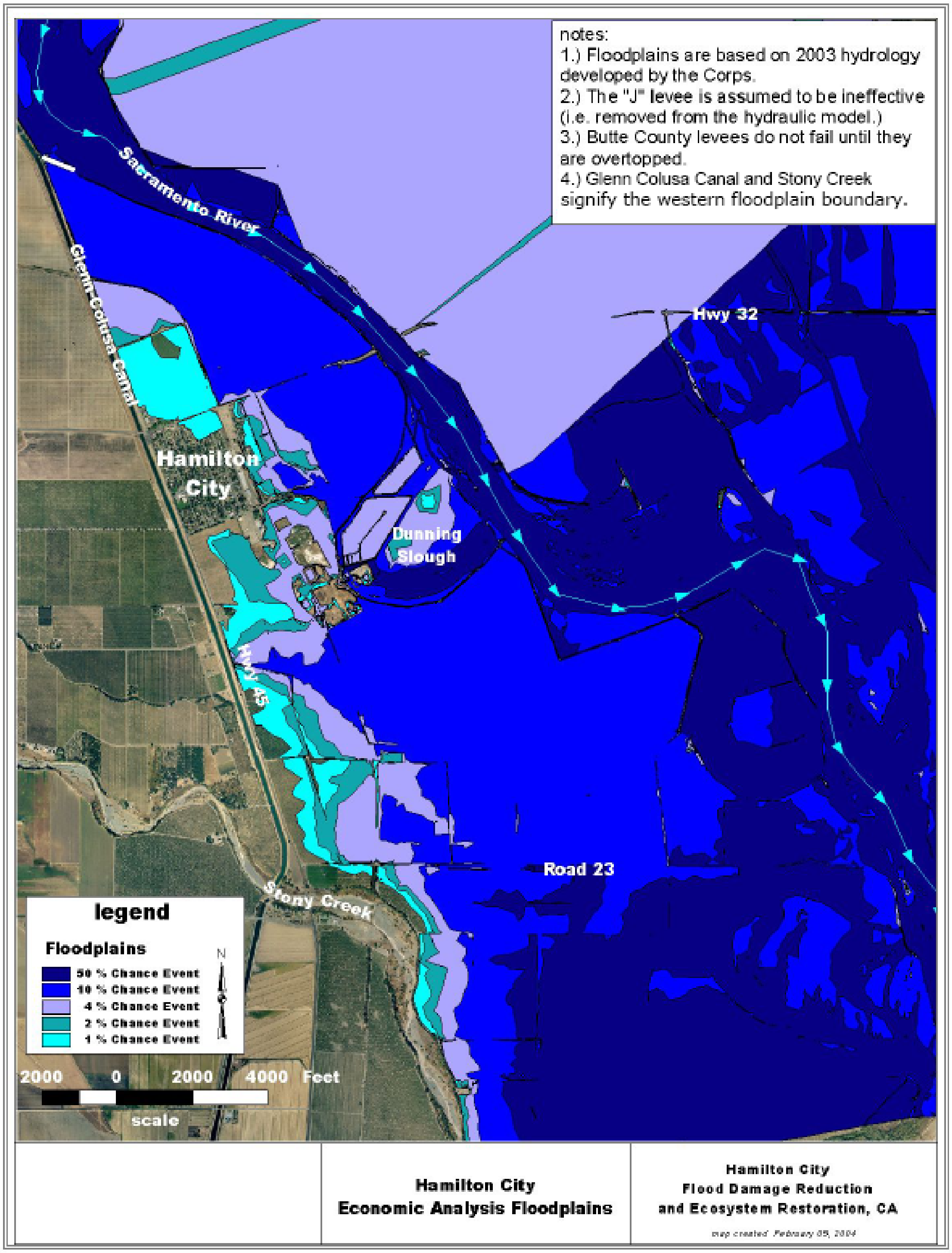
National Economic Development

The following tables illustrate the types of data that generally are required to perform flood risk management NED analyses.

Floodplains

Include figures showing without- project floodplains for each of the events included in the EAD analysis. If available, with-project floodplains should also be displayed. As an example, Figure EX-1 shows floodplains developed for the Hamilton City Flood Damage Reduction and Ecosystem Restoration Project.

Figure EX-1: Example Floodplains: Without-Project



Source: USACE and State Reclamation Board, *Hamilton City Flood Damage Reduction and Ecosystem Restoration Final Feasibility Report and EIS/EIR*, 2004.

Hydrology/Hydraulics (H&H) and Levee Failure

Provide summary data showing event frequencies and water surface elevations for without- and with-project conditions. If levees are included in the analysis, provide probability of levee failure functions (Table EX-2).

Table EX-2: H&H and Levee Failure

Flood Event	Event Frequency	Water Surface Elevation (ft)		Probability of Levee Failure (%)	
		Without Project	With Project	Without Project	With Project
n-Year					
n-Year					
n-Year					
n-Year					
n-Year					

Land Use
Provide summary existing and projected land use for without- and with-project conditions (Table EX-3).

Structural Inventories
Show the number of existing and projected structures at risk, such as residential, commercial, industrial, public facilities, etc., for without- and with-project conditions (Table EX-4). Table EX-5 displays structural values using depreciated replacement values.

Show the contents values of the without- project structures at risk, such as residential, commercial, industrial, public facilities, etc., using the following assumptions unless other information is available (Table EX-6) :

- Residential: 50% of structural value
- Commercial: 100% of structural value
- Industrial: 150% of structural value
- Public: 100% of structural value
- Other: 50% of structural value

Population. Estimate the population at risk for exisiting and projected conditions, without- and with-project (Table EX:-7)

Table EX-3: Land Use

Without Project

Flood Event	Urban		Agricultural		Native Vegetation		Other		Total	
	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj
n-Year										
n-Year										
n-Year										
n-Year										
n-Year										

With Project

Flood Event	Urban		Agricultural		Native Vegetation		Other		Total	
	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj
n-Year										
n-Year										
n-Year										
n-Year										
n-Year										

Table EX-4: Number of Structures at Risk

Without-Project

Flood Event	Residential		Commercial		Industrial		Public		Other		Total	
	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj
n-Year												
n-Year												
n-Year												
n-Year												
n-Year												

With Project

Flood Event	Residential		Commercial		Industrial		Public		Other		Total	
	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj
n-Year												
n-Year												
n-Year												
n-Year												
n-Year												

Table EX-5: Value of Structures at Risk

Without-Project

Flood Event	Residential		Commercial		Industrial		Public		Other		Total	
	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj
n-Year												
n-Year												
n-Year												
n-Year												
n-Year												

With Project

Flood Event	Residential		Commercial		Industrial		Public		Other		Total	
	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj
n-Year												
n-Year												
n-Year												
n-Year												
n-Year												

Table EX-6: Value of Contents at Risk

Without-Project

Flood Event	Residential		Commercial		Industrial		Public		Other		Total	
	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj
n-Year												
n-Year												
n-Year												
n-Year												
n-Year												

With Project

Flood Event	Residential		Commercial		Industrial		Public		Other		Total	
	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj	Exist	Proj
n-Year												
n-Year												
n-Year												
n-Year												
n-Year												

Table EX-7: Population at Risk

Flood Event	Without Project		With Project	
	Exist	Proj	Exist	Proj
n-Year				
n-Year				
n-Year				
n-Year				
n-Year				

Table EX-8: Event Damage

Flood Event	Event Probability	Event Damage		
		Without Project	With Project	Inundation Reduction Benefits
n-Year				
n-Year				
n-Year				
n-Year				
n-Year				
Expected Annual Damage				

Analysis Results
Display without- and with project event damage (for the recommended plan (Table EX-8). The difference between expected annual damage between without- and with- conditions is the *inundation reduction benefit*. Table EX-8 must be completed for existing year conditions and separately for projected conditions if included in the analysis.

Table EX-9 summarizes the NED net benefit analysis for the recommended plan based upon total present value of benefits and costs. This table includes all types of flood risk management benefits (inundation reduction, intensification and location) as well as benefits from other project objectives. Table EX-9 is completed for existing year conditions and separately for projected conditions if included in the analysis.[33] Table EX-10 displays the same information, but calculated on an annualized basis.

Table EX-10 displays the project performance statistics for the recommended plan if HEC-FDA was used.

Table EX -11 summarizes net benefits and benefit/cost estimates for all the alternatives that were analyzed. Detailed information for these other alternatives does not need to be displayed but must be available upon request.

[33] If projected conditions were not evaluated, then there would not be any intensification or location benefits.

Table EX-9: Total Present Value NED Net Benefits

Recommended Plan

(a)		Annual Benefits	
(b)		Flood Risk Management	
(c)		Inundation Reduction Benefits	
(d)		Intensification Benefits (1)	
(e)		Location Benefits (1)	
(f)	[c + d +e]	Subtotal Flood Risk Management	
(g)		Other Objectives (2)	
(h)	[f + g]	Subtotal Annual Benefits	
(i)		Present Value Coefficient (3)	15.67
(j)	[h x i]	Present Value of Future Benefits	
(k)		Project Costs	
(l)		Capital	
(m)		Annual Operations and Maintenance (O&M)	
(n)		Present Value Coefficient (2)	15.67
(o)	[m x n]	Present Value of O&M Costs	
(p)	[l + o]	Subtotal Project Costs	
(q)	[j – p]	NED Net Benefits	
(r)	[j / p]	NED Benefit/Cost Ratio	

(1) Intensification and location benefits may result from changes in land use caused by a project. However, DWR will not fund flood risk management projects providing primarily future land development opportunities, therefore "location" benefits will be excluded.

(2) Water supply, water quality, etc.

(3) 6% discount rate; 50-year analysis period.

Table EX-10: Annual NED Net Benefits

Recommended Plan

(a)		Annual Benefits	
(b)		Flood Risk Management	
(c)		Inundation Reduction Benefits	
(d)		Intensification Benefits (1)	
(e)		Location Benefits (1)	
(f)	[c + d +e]	Subtotal Flood Risk Management	
(g)		Other Objectives (1)	
(h)	[f + g]	Subtotal Annual Benefits	
(i)		Project Costs	
(j)		Capital	
(k)		Capital Recovery Factor (2)	0.06344
(l)	[j x k]	Annual Capital	
(m)		Annual Operations and Maintenance (O&M)	
(n)	[l + m]	Subtotal Annual Project Costs	
(o)	[h – n]	NED Net Benefits	
(p)	[h / n]	NED Benefit/Cost Ratio	

(1) Intensification and location benefits may result from changes in land use caused by a project. However, DWR will not fund flood risk management projects providing primarily future land development opportunities, therefore "location" benefits will be excluded.

(2) Water supply, water quality, etc.

(2) 6% discount rate; 50-year analysis period.

Table EX-11: HEC-FDA Project Performance Statistics

Project Performance Statistic	Without Project	Recommended Plan
Annual Exceedence Probability (1)		
Long-Term Risk (2)		
10 Year Period		
25 Year Period		
50 Year period		
Conditional Non-Exceedence Probability (3)		
10-Year Event		
25-Year Event		
50-Year Event		
100-Year Event		
250-Year Event		
500-Year Event		

(1) **Annual exceedence probability:** the annual probability of having a damaging flood event in a given year, such as a levee failure

(2) **Long-term risk:** the chance of having one or more damaging events over a period of time, similar to the question: what's the chance my house could be flooded during my 30 year mortgage?

(3) **Conditional non-exceedence probability:** the probability of containing specific flood events and avoiding damage**.**

Table EX-12: Comparison of Alternative Plans

Economic Measures	Alt. 1 (Recommended Plan)	Alt. 2	Alt. 3
Description			
Costs			
Capital			
PV O&M Costs			
Total			
Present Value Benefits			
Flood Risk Management			
Other			
Total			
Net Benefits			
Benefit/Cost Ratios			
Project Performance Statistics (1)			
Annual Exceedence Probability			
Long-Term Risk (25 Yrs)			
Conditional Non-Exceedence Probability (100-Yr Event)			

(1) If HEC-FDA was used.

Regional Economic Development

The RED analysis includes regional economic effects resulting from temporary construction activities as well as potential regional economic effects of reducing the likelihood of flooding.

Project Construction
Provide project construction costs (materials/equipment and labor), employment requirements and length of construction (Table EX-13). If I/O models are available, estimate direct, indirect and induced effects of project construction activities (Table EX-14).

Table EX-13: Construction Costs and Employment

Economic Measures	
Length of Construction *(No. of Years)*	
Year Project Begins Operation	
First Costs *($)*	
Materials and Equipment	
Labor (1)	
Total	
Employment *(Jobs)*	

(1) Includes wages, benefits and administrative overhead costs.

Table EX-14: RED Benefits: Construction

Economic Measures	Direct Effects	Indirect Effects	Induced Effects
Output (1) *($)*			
Value Added (2) *($)*			
Employment (3) *(Jobs)*			

(1) Direct output is the same as the project's capital costs.

(2) Direct value added includes employee compensation, proprietary income, other property income, and indirect business taxes.

(3) Direct employment includes the project's employment requirements.

Flood Effects

The goal of the RED analysis is to estimate the reduction in potential adverse regional economic effects caused by flooding. One way to do this is to focus upon the largest floodplain expected to be protected by the project. Economic activity within this protected floodplain will still be at risk, although with a lower probability of flooding if a project is implemented. Thus, for the largest floodplain protected by the project, information should be developed describing the economic activities at risk as well as the change in flood probabilities without and with the recommended plan. Table EX-15 displays existing condition business production (output), value added and employment at risk within the largest floodplain to be protected by a project; the total amounts of this activity within the county; and the percentage of the county total located within the floodplain. If I-O models are available, then the indirect and induced effects of disruptions in business production could also be displayed.[34] The information in Table EX-15 should be presented in the context of the change in the probability of flooding between the without and with project conditions (see Table EX-11).

[34] This analysis identifies economic activity at risk but does not address the more complicated question of how much of this lost economic activity disrupted by a flood event would be made up by increased business activity outside of the floodplain, or the "net" loss of economic activity.

Table EX-15: Business Production (Output) at Risk

Economic Measure	Largest Protected Floodplain	Total Within County	% of County
Output (1)			
Value Added (2)			
Employment			

(1) Value of goods and services produced.

(2) Includes employee compensation, proprietary income, other property income, and indirect business taxes.

The estimation of RED flood-related effects can be very complex. At a minimum, the RED analysis should include a qualitative description of the types of businesses at risk from flooding, particularly those that could have a significant adverse impact (output, employment, etc.) upon the community or regional economies if their operations should be disrupted by flooding and how this would be affected by the recommended project.

Other Social Effects

The goal of the OSE analysis is to estimate the reduction in potential other social effects caused by flooding. One way to do this is to focus upon the largest floodplain expected to be protected by the project. Population within this protected floodplain will still be at risk, although with a lower probability of flooding if a project is implemented. Thus, for the largest floodplain protected by the project, information should be developed describing the population at risk as well as the change in flood probabilities without and with the recommended plan.

Population at risk

Compare estimates of total population and flood-vulnerable groups at risk, such as elderly, low-income, minorities, etc., for the largest floodplain to be protected by the project with total county estimates (Table EX-16). The information in Table EX-16 should be presented in the context of the change in the probability of flooding between the without and with project conditions (see Table EX-11).

Since this population is at risk of being displaced by flood events, determine the number of potential shelter and evacuation facilities not likely to be directly affected by the flood event (Table EX-17). This type of analysis can be greatly enhanced by using GIS to map potential inundation areas (extents and depths) for given time periods (i.e., 6, 12, 24, 48 hours, etc.) into a flood event. For example, after 6 hours, a flood event could be shown to cover *x* acres with depths up to *y* feet, displacing *z* people.

Critical facilities at risk

Compare the number of critical facilities at risk, such as hospitals, emergency response, schools, utilities, transportation, etc., for the largest floodplain to be protected by the project with total county estimates (Table EX-18). Information in this table can be enhanced by providing descriptive information concerning the facilities (for example, number of beds in hospitals, number of students in schools, etc.).

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Table EX-16: Population at Risk

Population Groups	Largest Protected Floodplain (N-Year)	Total Within County	Floodplain as % of County
Population			
Households			
Population Older Than 65 Years			
Population Younger Than 18 Years			
Low-Income Population			
Minorities			
Other			

Table EX-17: Potential Shelter Facilities

Population Groups	Not Directly Affected	Total Within County	% Not Directly Affected
Designated Shelters			
Hotels/Motels			
Sports Facilities			
Other			

Table EX-18: Number of Critical Facilities at Risk

Critical Facilities	Largest Protected Floodplain (N-Year)	Total Within County	Floodplain as % of County
Medical Care			
Emergency Response			
Schools			
Utilities			
Transportation Systems			
Other..			

Flood insurance coverage
If households that are displaced by flooding have flood insurance coverage, then the odds are improved for them to better recover from the physical effects of the flood (and more quickly) than those who do not have flood insurance. Table EX-19 compares the total number of parcels within communities potentially affected by flooding with those that have flood insurance; the larger the percentage, the better. NFIP insurance information can be obtained from FEMA's Community Information System database.

Table EX-19: Number of Parcels with Flood Insurance

Communties	Total Number of Parcels	Parcels with Flood Insurance	%
Community *a*			
Community *b*			
Community *c*			
Other			

Chapter 7: Flood Economics Resources

USACE
Planner's Library

- *Planning Manual*
- *Planning Guidance Notebook* (ER 1105-2-100)
- *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*
- Economic Guidance Memoranda (interest rates, depth-damage curves, unit day values, etc.)

http://www.usace.army.mil/cw/cecw-cp/library/planlib.html

Flood Risk Management Engineering Manuals and Regulations

- EM 1110-2-1619, *Risk-Based Analysis for Flood Damage Reduction Studies*, August, 1996
- ER 1105-2-101, *Risk Analysis for Flood Damage Reduction Studies*, January 2006.

http://140.194.76.129/publications/index.html

National Economic Development Manuals (Revised Web-based Versions)

- Flood Risk Management
- Coastal Storm Risk Management

http://www.iwr.usace.army.mil/ned/

National Economic Development Manuals (Original Text Versions)

- *National Economic Development Procedures Manual – Urban Flood Damage* (IWR Report 88-R-2), March 1988

- *National Economic Development Procedures Manual – Agricultural Flood Damage* (IWR Report 87-R-10), March 1988

- *National Economic Development Procedures Manual – Overview Manual for Conducting National Economic Development Analysis* (IWR Report 91-R-11), October 1991.

  http://www.iwr.usace.army.mil/inside/products/pub/pubsearchS.cfm?series=NED

Hydrologic Engineering Center

- HEC-FDA software and documentation (manual and certification report)

- HEC-FIA software (currently under development)

  http://www.hec.usace.army.mil/

National Flood Risk Program

  http://www.iwr.usace.army.mil/nfrmp/

FEMA

- HAZUS-MH

  http://www.fema.gov/plan/prevent/hazus/index.shtm

- Mitigation Benefit-Cost Analysis Software

  http://www.fema.gov/government/grant/bca.shtm

- Mitigation BCA Toolkit (including "What is a Benefit?" publication) is available at FEMA Regional Offices or by contacting the BC Helpline bchelpline@dhs.gov or calling (866) 222-3580

- President's Office of Management and Budget, Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs, (October 29, 1992) [used by FEMA]

  http://www.whitehouse.gov/omb/rewrite/circulars/a094/a094.html

DWR

- *Economic Analysis Guidebook* (January 2008)

  http://www.economics.water.ca.gov/guidance.cfm

- Comprehensive Floodplain Management: Promoting Wise Uses of Floodplains (workshop modules)

  http://www.economics.water.ca.gov/studies.cfm

- *Quick Guide: The NFIP in California*

  http://www.fpm.water.ca.gov/

Other

President's Council on Environmental Quality

- Updated Federal *Principles & Guidelines for Water and Related Land Resources Implementation Studies*

  http://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG

Associated Programme on Flood Management

- *Integrated Flood Management: Concept Paper* (2004)
- *Conducting Flood Loss Assessments: A Tool for Integrated Flood Management* (March 2007)
- *Economic Aspects of Integrated Flood Management* (June 2007)

  http://www.apfm.info/ifm_tools.htm

Association of State Floodplain Managers

http://www.floods.org/

Floodplain Management Association

http://www.floodplain.org/

National Park Service (Rivers, Trails and Conservation Program)

- *Economic Impacts of Protecting Rivers, Trails and Greenway Corridors* (1995)

http://www.nps.gov/ncrc/programs/rtca/helpfultools/ht_publications.html

National Research Council/National Academy of Sciences

- *Flood Risk Management and the American River Basin* (1995)
- *Risk Analysis and Uncertainty in Flood Damage Reduction Studies* (2000)
- *The Impacts of Natural Disasters: A Framework for Loss Estimation* (1999)
- *Analytical Methods and Approaches for Water Resources Project Planning* (2004)
- *Valuing Ecosystem Services* (2005)

http://www.nap.edu/

L. Douglas James and Robert R. Lee, *Economics of Water Resources Planning* (1971)

Appendix I: Levee Incremental Benefit Analysis

Report on Alternatives Analysis

Phase IV: Feather River Levee Repair Project

APPENDIX VI

INUNDATION REDUCTION BENEFIT ANALYSIS

Prepared for

Three Rivers Levee Improvement Authority

Prepared by

David Ford Consulting Engineers, Inc.

and Flood Control Study Team

December 2006

HOW WE COMPUTED EXPECTED ANNUAL DAMAGE AND PROJECT PERFORMANCE STATISTICS

Using the information described in the previous chapter, we used computer program HEC-FDA to compute EAD and project performance statistics for each impact area and index point. In this section, we describe how we related index points to the impact areas, in many cases using multiple index points, to compute EAD for each impact area using HEC-FDA.

DESIGNATION OF INDEX POINTS TO IMPACT AREAS

In Figure VI-6*a*, we show the simplest case of EAD computation. Here, a single index point is designated as representative of the hydrologic, hydraulic, and geotechnical conditions for an impact area. In this case, we use a relationship of the interior (floodplain) elevation to exterior elevation at the index point to represent the flooding depth of the interior structures and to compute EAD.

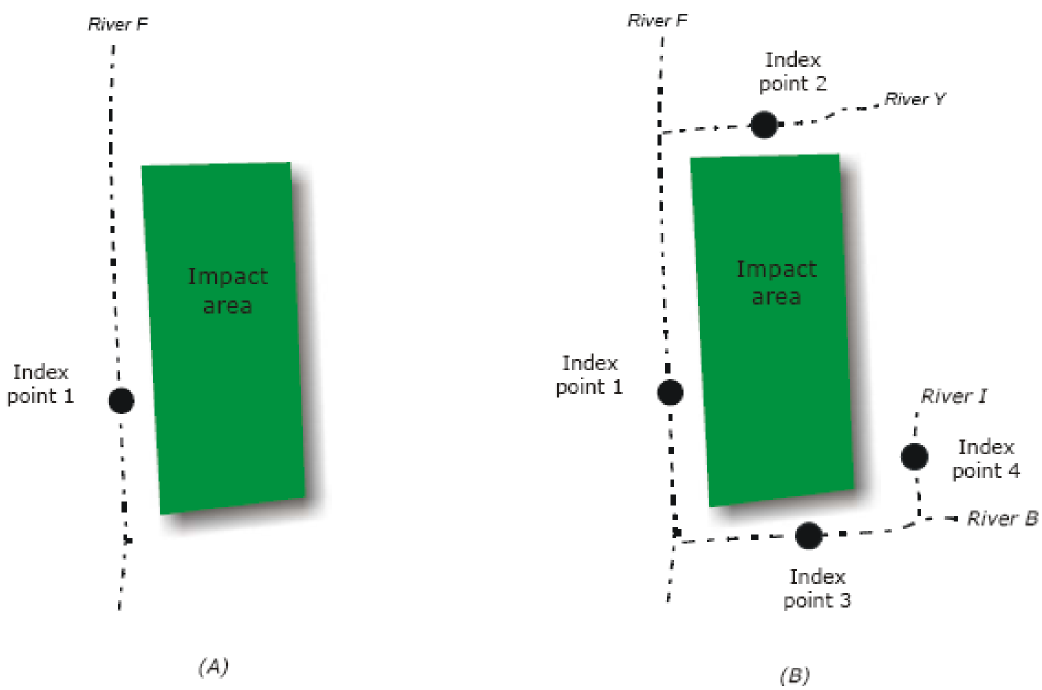

FIGURE VI-6. IMPACT AREA WITH INDEX POINT

However, for an area surrounded by levees, the hydrologic and hydraulic conditions may vary in the surrounding watercourses, especially when the impact area is adjacent to a major confluence. Additionally, failures at any of the surrounding levees will result in major flood damage. Thus, a single primary source of flooding does not exist, and a single index point does not represent the flood risk well. For these cases, we designate multiple index points to the impact area. This case is illustrated in Figure VI-6*b*. Here, inundation damage can result from failures at each of the four index points.

In either case, there is only a single EAD value for an impact area. But the EAD for the impact area is not simply the sum of the EAD values computed with information for the individual index points; to compute it in this way would overestimate the damage potential. Instead, the EAD value is a weighted average of the EAD values computed at each index point. A single index point is simply a special case where the weight assigned to the EAD value is 1.0. For multiple index points, the weights can either be determined through expert judgment, analysis of historical data, or through some other objective procedure.

The weight used for each source-specific EAD value represents the probability of damage resulting from a levee failure at that index point, given a levee failure occurs in any given year. Thus, if a levee is strengthened or altered in some way, the weight used for that index point must change to reflect this modified condition and associated flood risk. For these scenarios where the weights change between plans, an objective procedure to quantify the risk of levee failure from each index point is best.

For this economic analysis, the levees surrounding RD784 are modified as components of the plans evaluated. Thus, we require an objective procedure to determine the weights for computing the single-value EAD for RD784 (IA1) for each plan. Here, we used the annual exceedence probability (AEP) as the tool to develop the weights for these levees. The AEP is the annual probability that the interior floodplain in an impact area will be inundated due to channel or levee overtopping or failure. Included in the AEP are the stage-frequency function, the levee performance function, and the uncertainty in each. Smaller values of AEP indicate a lower risk of flood damage in the reach in any given year.

To compute conditional probabilities using AEP, we use the equation

$$P_i = \frac{AEP_i}{\sum_{i=1}^{n} AEP_i} \tag{1}$$

where P_i = the weight designated to a specific index point (and thus a source-specific EAD value); n = the number of index points designated to an impact area; and AEP = the annual exceedence probability at index point i. Note that the sum of the probabilities for a given impact area must equal 1.0.

IMPACT AREAS WITHIN THE ECONOMIC STUDY AREA WITH A SINGLE INDEX POINT

EAD was computed using a single index point for the following impact areas:

- IA2 (Yuba City), computed using a stage-frequency function at FR-1.
- IA3 (Marysville), computed using a stage-frequency function at JS-1.

Because a single index point was used to compute the EAD values for these impact areas, the weight associated with each source-specific EAD value using equation 1 was 1.0. In other words, in equation 1, $n = 1$, thus the numerator and denominator in the equation are equal.

IMPACT AREAS WITHIN THE ECONOMIC STUDY AREA WITH MULTIPLE INDEX POINTS ON PROJECT LEVEES

For the EAD computations in IA1 (RD784), we use a multiple index point approach. Because the levee parameters at each index point change from the without-project condition and between plans, the weights used to compute a single EAD value must also change. In the plans, the levees are either setback or strengthened, or a combination.

From the exterior-interior relationship provided by MBK Engineers (included in Attachment VI.3), we see that each sub-area is not inundated by flooding at each index point. For example, a levee failure along the Bear River does not result in flooding of the northern portion of RD784. For the EAD computations, we consider each sub-area separately, using the exterior-interior relationships to identify which index points result in flooding in a specific sub-area, given a levee failure. The tables in Attachment VI.3 show these relationships between index points and sub-areas.

We used equation 1 to compute weights for each index point for each plan evaluated, considering the calculations on a sub-area basis. The AEP values used in the equation are listed in column 3 of Table VI-7 through Table VI-14. The results of equation 1 are included in column 4. These weights are then used with the source-specific EAD value to compute a weighted-average EAD value for the sub-areas. The weighted-average EAD value for each sub-area is then summed to get the EAD value for the impact area.

For example, to compute the weight for the Yuba River RM 1.14 index point for the without-project condition for a sub-area in the southern portion of RD784, we use equation 1 and the information listed in Table VI-7 as such:

$$P_{Yuba} = \frac{0.0191}{0.0058 + 0.0191 + 0.0548 + 0.0538 + 0.0523} = 0.10 \qquad (2)$$

The weight assigned to this index point is 0.10. The equation is again used for each index point to compute the weights listed in column 4 of Table VI-7 for the other index points.

Using the information about each index point, the elevation-damage functions for the IA1 sub-areas, and the appropriate exterior-interior relationship between the two, we computed source-specific EAD values using HEC-FDA for all the sub-areas. For example, the source-specific EAD values for sub-area RD-13 (southern RD784) are:

- $162,000 from the Yuba River (YR-1)
- $821,000 from Yuba River (YR-2)
- $4,838,000 from the Feather River
- $1,837,000 from the Bear River
- $2,937,000 from the Interceptor Canal

The weighted-average value is then computed as:

$$\begin{aligned} EAD_{RD-13} &= 0.03(162{,}000) + 0.10(821{,}000) + 0.29(4{,}838{,}000) \\ &\quad + 0.29(1{,}837{,}000) + 0.28(2{,}937{,}000) = \$2{,}875{,}000 \end{aligned} \tag{3}$$

This process is repeated for each sub-area and the sum is the without-project EAD for IA1. This process is repeated for each alternative plan evaluated.

Examining the weights used for the analysis, we can see that for the without-project condition, the EAD value from a Yuba River failure at RM 1.55 has the least weight. Thus, a levee failure into RD784 at this location is the least likely to occur when compared to a failure along the other levees or at the other Yuba River index point. For each of the plans, the weights are relatively equal, thus representing an approximately equal risk of levee failure from each levee.

TABLE VI-7
WITHOUT-PROJECT CONDITION AEP AND NORMALIZED WEIGHTS FOR RD-9, RD-11, RD-12, AND RD-13

Index point (1)	Index point (2)	AEP (3)	EAD weight (P_i) (4)
YR-1	Index point Yuba River, RM 1.55	0.0058	0.03
YR-2	Index point Yuba River, RM 1.14	0.0191	0.10
FR-4	Index point Feather River, RM 19.00	0.0548	0.29
BR-1	Index point Bear River, RM 3.44	0.0538	0.29
IC-1	Index point Interceptor Canal, RM 2.44	0.0523	0.29

TABLE VI-8
WITHOUT-PROJECT CONDITION AEP AND NORMALIZED WEIGHTS FOR RD-5, RD-6, AND RD-7

Index point (1)	Index point (2)	AEP (3)	EAD weight (P_i) (4)
YR-1	Index point Yuba River, RM 1.55	0.0058	0.23
YR-2	Index point Yuba River, RM 1.14	0.0191	0.77

TABLE VI-9
PLAN 1 AEP AND NORMALIZED WEIGHTS FOR RD-9, RD-11, RD-12, AND RD-13

Index point (1)	Index point (2)	AEP (3)	EAD weight (P_i) (4)
YR-1	Index point Yuba River, RM 1.55	0.0043	0.24
YR-2	Index point Yuba River, RM 1.14	0.0037	0.21
FR-4	Index point Feather River, RM 19.00	0.0040	0.23
BR-1	Index point Bear River, RM 3.44	0.0030	0.17
IC-1	Index point Interceptor Canal, RM 2.44	0.0026	0.15

TABLE VI-10
PLAN 1 CONDITION AEP AND NORMALIZED WEIGHTS FOR RD-5, RD-6, AND RD-7

Index point (1)	Index point (2)	AEP (3)	EAD weight (P_i) (4)
YR-1	Index point Yuba River, RM 1.55	0.0043	0.54
YR-2	Index point Yuba River, RM 1.14	0.0037	0.46

TABLE VI-11
PLAN 2 AEP AND NORMALIZED WEIGHTS FOR RD-9, RD-11, RD-12, AND RD-13

Index point (1)	Index point (2)	AEP (3)	EAD weight (P_i) (4)
YR-1	Index point Yuba River, RM 1.55	0.0037	0.23
YR-2	Index point Yuba River, RM 1.14	0.0031	0.19
FR-4	Index point Feather River, RM 19.00	0.0036	0.22
BR-1	Index point Bear River, RM 3.44	0.0032	0.19
IC-1	Index point Interceptor Canal, RM 2.44	0.0027	0.17

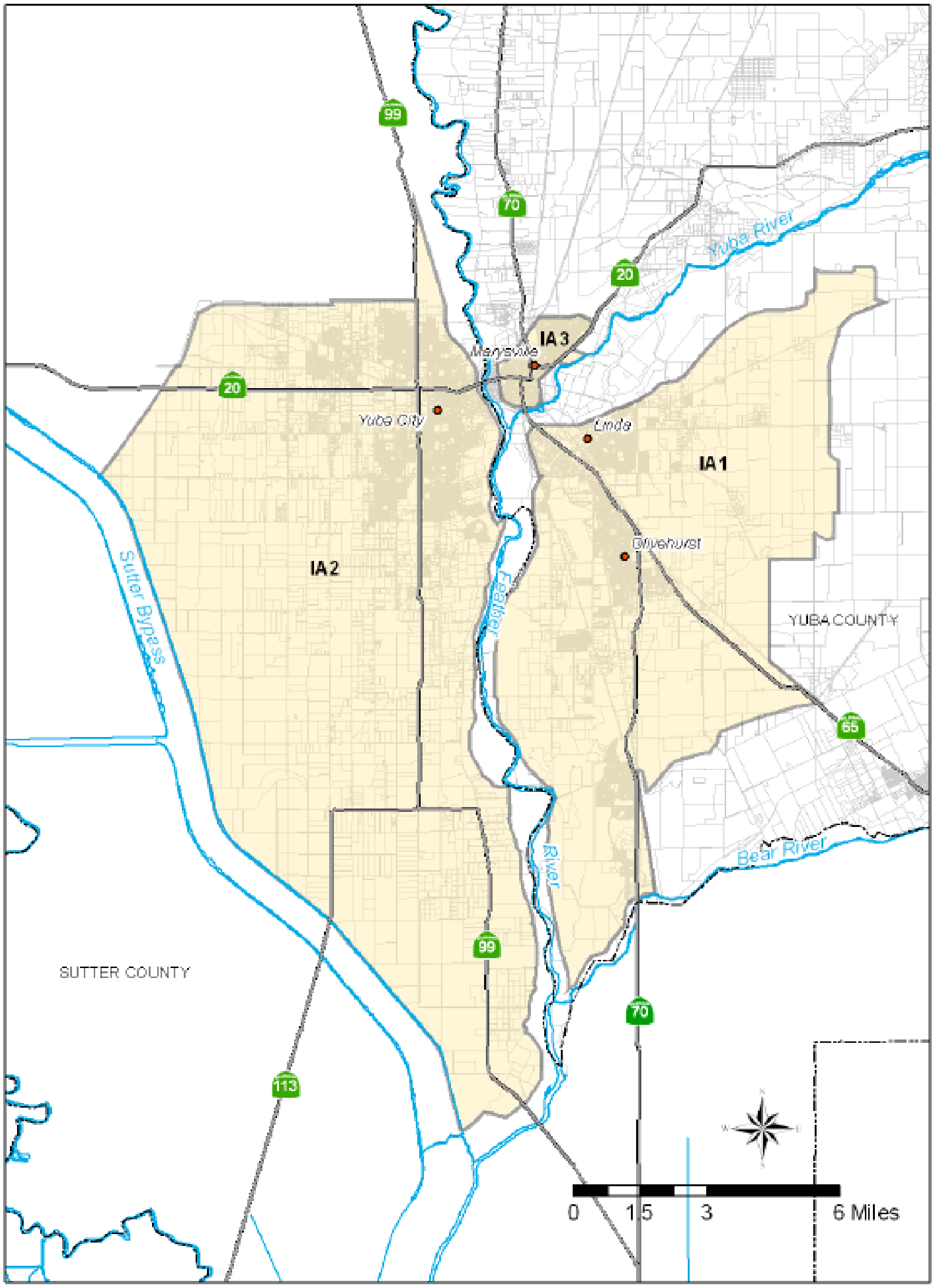

FIGURE VI-1. REGIONAL ECONOMIC STUDY IMPACT AREAS

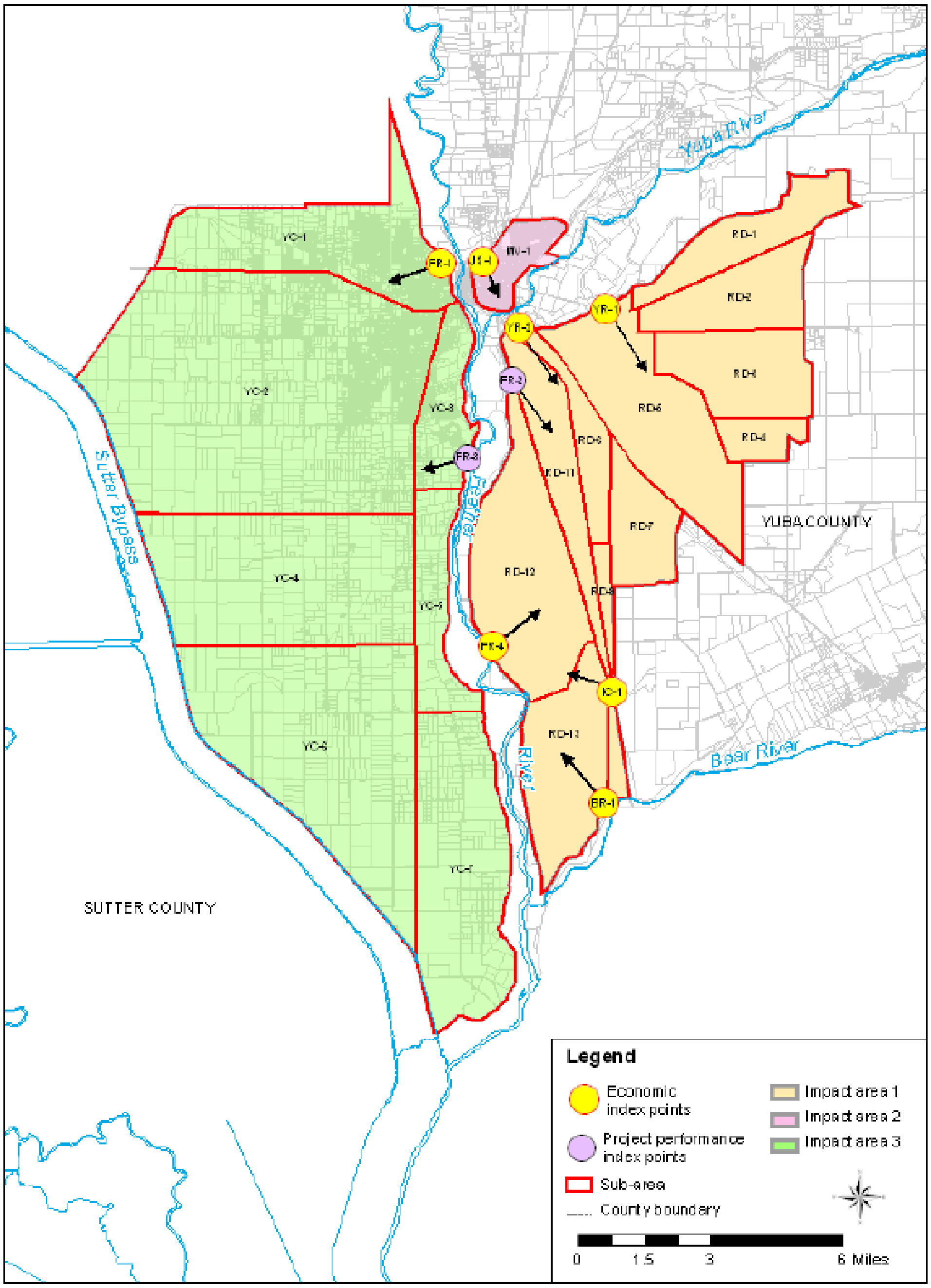

FIGURE VI-2. INDEX POINTS AND ANALYSIS SUB-AREAS